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EVALUATION OF THE EXPERIMENTAL MODEL OF THE RADAR SET GROUP OA-2003(XN-1)/ASB

(U)

By

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334 212

ABSTRACT. This report discusses the results of the flight testing and evaluation of the experimental model of the Radar Set Group OA-2003(XN-1)/ASB. The characteristics and performance of this equipment are detailed, and certain improvements in design that were suggested for the developmental model are discussed.

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China Lake, California

October 1962

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FOREWORD

The flight testing of the experimental model of the Radar Set Group OA-2003(XN-1)/ASB was conducted at the U. S. Naval Ordnance Test Station, China Lake, California, to evaluate the engineering design and the performance characteristics of this special radar set that had been developed as a component of the Bomb Directing Set AN/ASB-8. The evaluation of the experimental model of the radar led to design improvements in the developmental model.

This evaluation was carried out in 1959 and 1960 under Bureau of Naval Weapons Task Assignment RAV 32N001/261-1/r008-02-002.

This report has been reviewed for technical accuracy by
Edwin F. Park and John H. Gregory.

Released by
N. E. WARD, Head
Aviation Ordnance Department
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Under authority of
WM. B. MCLEAN
Technical Director

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ii

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CONTENTS

Introduction	1
General Performance	6
Performance and Modifications	22
Antenna Assembly	22
Transmitter—Modulator	22
Receiver Unit	22
Synchronizer	23
Recording Storage Unit and Indicators	26
Appendices	
A. Modes of Operation	51
B. Functional Description of Equipment	55

Figures:

1. Radar Set Group OA-2003/ASB, Rear View of Antenna, Showing Microwave Section and Preamplifiers	2
2. Antenna With Spoiler in Fan-Beam Position	3
3. Antenna With Spoiler in Pencil-Beam Position	4
4. Radar Set Group OA-2003/ASB Block Diagram	5
5. 120-Mile Displays Showing Difference in Antenna Gain	9
6. Displays Showing Difference in Antenna Gain Between Wide-Pulse Pencil-Beam and Fan-Beam Operation	9
7. Comparison of Short-Range Narrow-Pulse and Wide-Pulse Displays, Mothball Fleet, San Suisun Bay	10
8. Comparison of Short-Range Narrow-Pulse and Wide-Pulse Displays, San Francisco Area	10
9. Displays Showing Undesirable Characteristics of Receiver Noise	11
10. Comparison of Σ Only and MRI Operation, San Francisco Bay Bridge	11
11. MRI Displays, Naval Air Facility, China Lake	12
12. Comparison of Σ Only and MRI Operation, Los Angeles Area (Long Beach)	12
13. Radar Target, Mothball Fleet, San Suisun Bay	13
14. Radar Target, San Francisco Area, Including San Suisun Bay	14
15. Comparison of Σ Only and MRI Operation, Mothball Fleet, San Suisun Bay	15
16. Comparison of Σ Only and MRI Operation, San Francisco Area, Showing Golden Gate Bridge, Bay Bridge, Richmond—San Rafael Bridge	15

17. Displays Showing Distortion, San Francisco Area	16
18. Displays Showing Distortion, Mothball Fleet, San Suisun Bay	17
19. Displays Showing Improvement of Distortion	17
20. Bombing—Navigation Mode, Unexpanded Display; San Francisco Bay Bridge and Treasure Island	18
21. Radar Target, Los Angeles Area, Including Long Beach	20
22. Radar Target, San Diego Area	21
23. Comparison of Ground-Test Displays Before Changes to MRI Circuitry	28
24. Comparison of Ground-Test Displays Following Addition of Series Clipper to MRI Circuit	29
25. Comparison of Ground-Test Displays Employing Elevation MRI Circuit in Azimuth With Series Clipper	30
26. Comparison of Ground-Test Displays Employing MRI Replacement Circuit of Fig. 27	31
27. MRI Replacement Test Circuit	32
28. NAFI-Developed MRI Circuit	33
29. Depression-Angle Readout Error Versus Askania Depression Angle	34
30. Displays from 20,000 Feet	45
31. Terrain Clearance, Range Height Indicator	46
32. Terrain Clearance, E-Scan	46
33. False Targets, "Shadows"	47
34. False Targets, "Wings"	47
35. Terrain Clearance, E-Scan; Death Valley Area	48
36. Terrain Clearance, E-Scan; Mono Lake Area	49
37. Control Panel	50
38. Transmitter—Modulator	56
39. Receiver	57
40. Comparator and Four-Horn Feed Assembly	58
41. Synchronizer	61
42. Servo Unit No. 1	63
43. Servo Unit No. 2	64
44. Recording Storage Unit	65
45. Navigator's Indicator	66
46. Pilot's Indicator	67
47. Junction Box	67

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INTRODUCTION

The Radar Set Group OA-2003/ASB, designed to perform search, bombing-navigation, and terrain-clearance functions, was developed specifically for use in high-performance attack aircraft as a component of the Bomb Directing Set AN/ASB-8. It was developed for the Bureau of Naval Weapons by Stavid Engineering, Inc., Plainfield, New Jersey, under U. S. Naval Ordnance Test Station (NOTS) contract N123(60530)11890A, of 27 March 1957. The contract originally required the delivery of an experimental model within 18 months, a developmental model within 24 months, and a production prototype within 30 months of the contract date. Owing to extreme delays in development, the contract was later amended to require only the first two models.

The experimental model of the Radar Set Group OA-2003(XN-1)/ASB was delivered to NOTS on 17 July 1959 for evaluation. The flight-test program in a P2V-4 aircraft began in November 1959 and continued through July 1960. Bench tests were conducted prior to the aircraft installation.

The Radar Set Group OA-2003/ASB (Fig. 1, 2, 3, and 4) is a four-horn monopulse Ku-band radar, tunable over the range of 16 to 17 gigacycles (gc), with a rated peak power output of 60 kilowatts (kw). The four-gimbaled antenna is stabilized in roll and pitch to the vertical; in azimuth to the aircraft datum line (ADL), the aircraft drift angle, or the horizontal line of sight (LOS); and in elevation to the angle of attack, the horizontal, or the elevation LOS. The radiated beam is either pencil or fan shaped (cosecant-squared) in the vertical plane, and pencil shaped in the horizontal plane.

The radar set was designed to fulfill the forward-looking radar functions of the Bomb Directing Set AN/ASB-8. It was developed to provide an all-operational altitude, all-weather capability for navigation and bombing in heavy-attack aircraft and was designed to fit the nose of a typical high-performance jet aircraft (particularly the A3J-1).

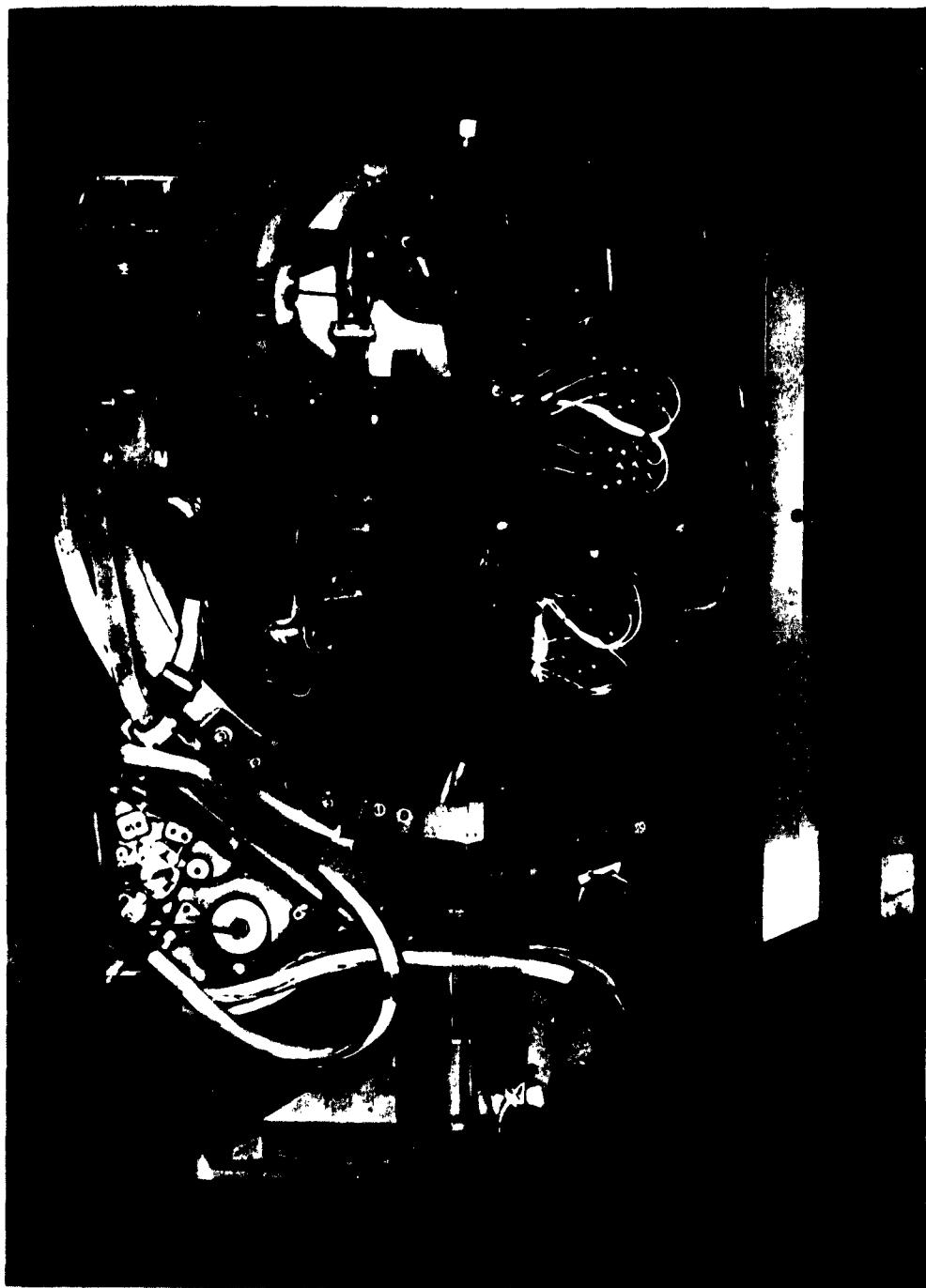


FIG. 1. Radar Set Group OA-2003/ASB, Rear View of Antenna,
Showing Microwave Section and Preamplifiers.

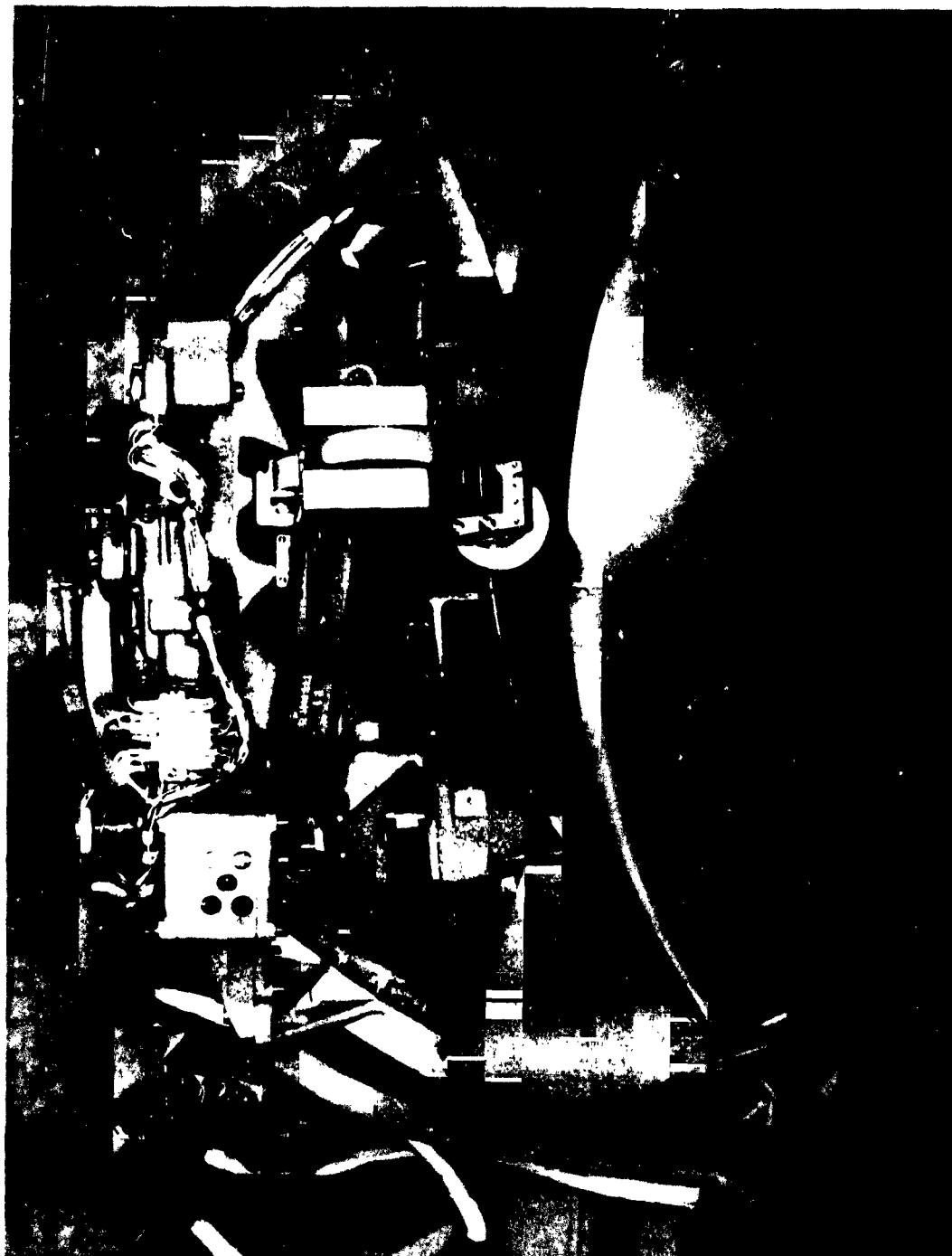


FIG. 2. Antenna With Spoiler in Fan-Beam Position.

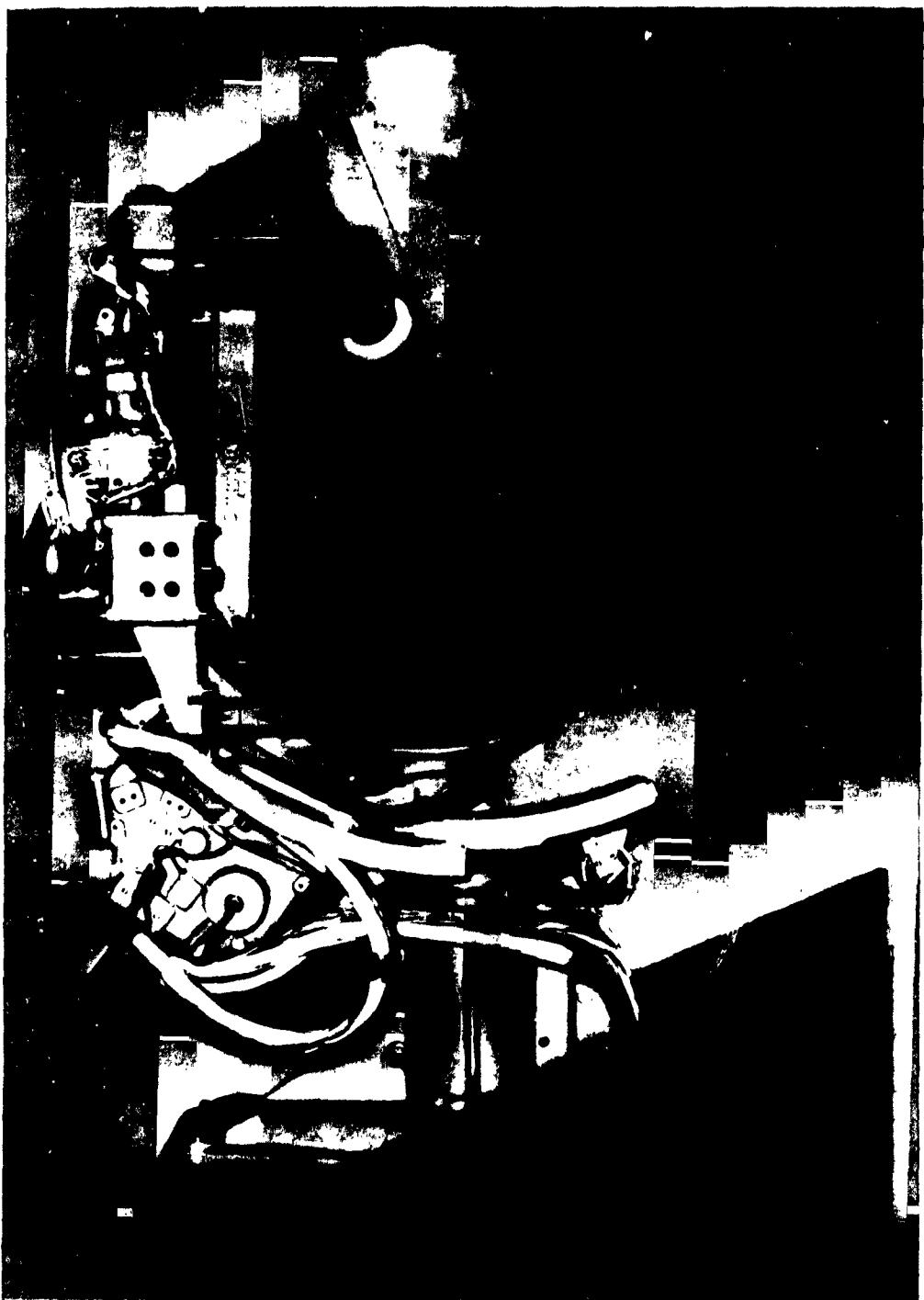


FIG. 3. Antenna With Spoiler in Pencil-Beam Position.

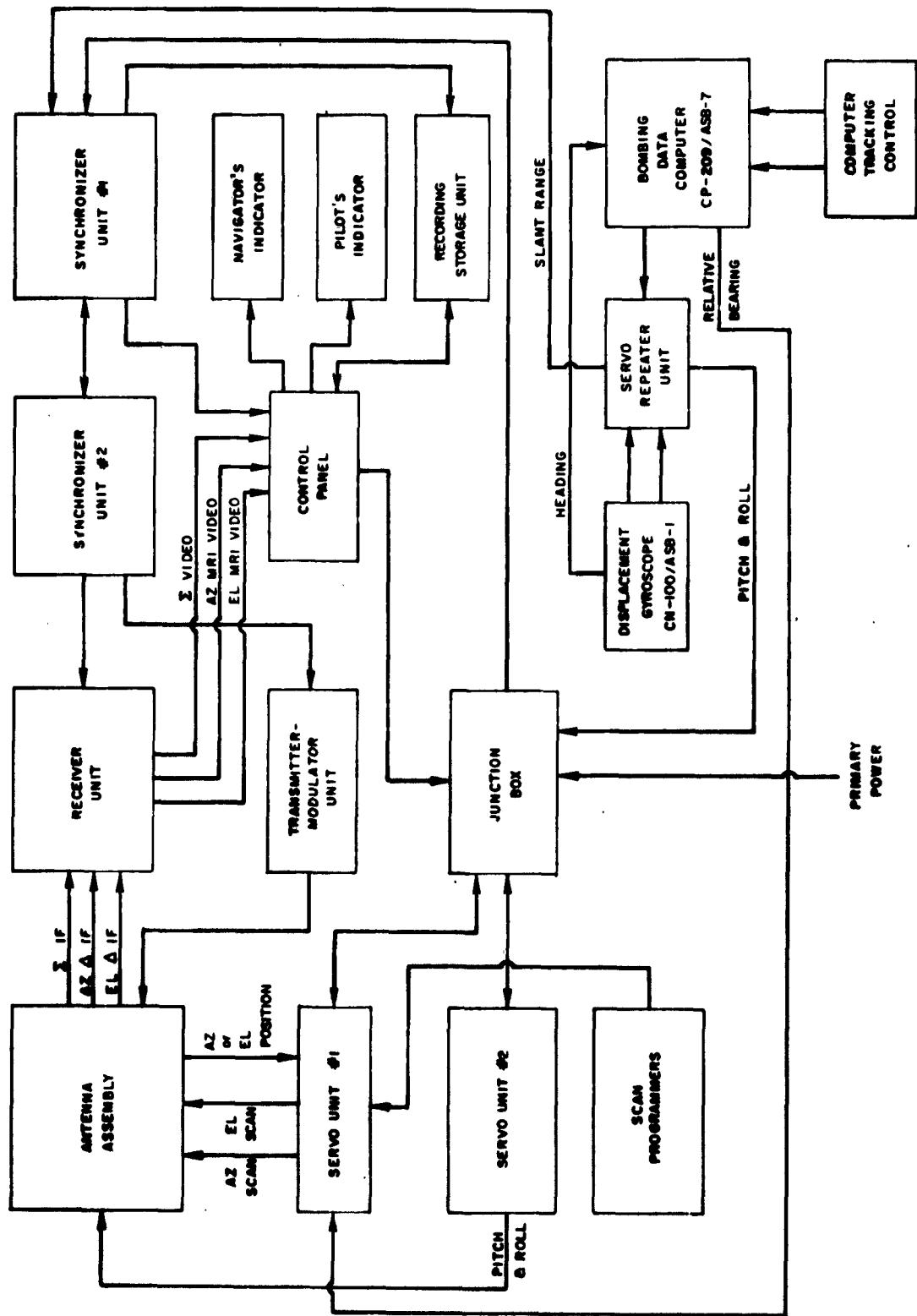


FIG. 4. Radar Set Group OA-2003/ASB Block Diagram

A feature of this radar is improved resolution in both azimuth and elevation which is achieved by comparing appropriate combinations of the components of the radar return, thereby developing sharp, direction-sensitive nulls in the reception pattern. This monopulse resolution improvement (MRI) technique is used to formulate the precise data required for accurate tracking and for better target identification during bombing-navigation and terrain-clearance operations.

Antijamming features such as tunability, radar silence, and special receiver design are incorporated. Letdown and low-altitude penetration capabilities are provided by the terrain-clearance function.

GENERAL PERFORMANCE

The experimental model of the radar set was to demonstrate the feasibility of design in meeting specified operational requirements imposed upon it. This model was built for flight testing, but it was not intended to meet the weight, size, or shape requirements of any particular type of aircraft. Consequently, the scope of the flight-test program was to evaluate the performance of the radar against the specified design requirements. These include search and mapping, ranging, resolution, target recognition, suitability of displays, terrain clearance, "track-while-scan" operation, reliability, and ease of maintenance.

For the flight-test program, the bombing-navigation computer functions were supplied from the Bombing Data Computer CP-209/ASB-7, and the vertical reference information from the Displacement Gyroscope CN-100/ASB-1. Since the radar set required an analog two-speed synchro slant-range data input from the computer and 1:1 pitch and roll synchro inputs from the vertical gyro, servo transformation of the available output data was required. As Fig. 4 shows, the servo repeater unit transformed the slant-range digital output of the CP-209 and the 2:1 pitch and roll outputs of the CN-100 to those required by the radar. The relative bearing output of the CP-209 did not require change. Drift-angle and angle-of-attack data were not furnished from aircraft sensors; therefore, synchro zero-reference transformers were applied to these radar inputs.

The data recording instrumentation employed in the test program (not shown in Fig. 4) consisted of a servo repeater, a demodulator and oscillograph on the radar depression-angle output, a Beattie Varitron 70-mm pulsed camera and optical periscope assembly on the navigator's indicator, and an oscilloscope to observe signal returns and test points.

Initial flight tests were to establish search and mapping performance characteristics. The results indicated a serious loss in long-range sensitivity when the radar was switched from narrow-pulse to wide-pulse operation.

After a time, the loss of sensitivity was significantly improved by a redesign of the band-pass filter network in the receivers. Following the receiver corrections, search operations to the design goal of 120 nautical miles (n. mi.) were achieved in pencil-beam operation against hard targets; fan-beam operation resulted in ranges to 60 n. mi. (Fig. 5). There was approximately a 6-decibel (db) difference in antenna gain between pencil-beam and fan-beam operation (Fig. 5). Figure 6 also illustrates the difference in antenna gain.

The antenna assembly design and performance proved very good, except for the high loss in gain between fan and pencil beam, the azimuth drive gearing, and the azimuth scan system. On the antenna drive assembly, the gearing mechanisms were not strong enough for continued operation, and the antenna drive motors were not adequate for the rapid scanning rates required in high-performance aircraft. The four-channel microwave portion, the preamplifiers, the automatic frequency control (AFC), and the local oscillator proved reliable and adequate.

The presentation displayed on the navigator's indicator, conventional cathode-ray tube (CRT), showed a combination of video distortion, 400-cycle noise, inadequate contrast, and initially insufficient gain to permit the display of receiver noise (Fig. 7, 8, 17, 18, and 31). Figure 9 illustrates the undesirable characteristics of noise in the display when sufficient gain was provided and the variation in the noise level with the change in pulse repetition frequency (PRF). The video distortion and the noise problems were largely associated with poor grounds and inadequate shielding of the wiring within the indicator. The noise problem was never completely eliminated, but was improved in time. The inadequate contrast and receiver noise problems were found to have been caused by the video processing circuit where the video, markers, and the unblanking pedestal were mixed, and were attributed to poor direct-current (d.c.) restoration. In time, the contractor provided a newly designed circuit that greatly improved the problem (Fig. 10, 11, 12, 15, 16, 19, and 20).

It was evident from the outset that MRI operation in azimuth was totally inadequate. This was considered the major design deficiency of the radar set. The trouble was pinpointed to the sum (Σ) and difference (Δ) video processing circuits. Throughout the flight-test program, considerable effort was expended by both NOTS and contractor personnel in designing suitable circuitry to achieve the desired results. A circuit design that could adequately improve resolution in azimuth could not be made compatible with the receiver as designed. Figures 10, 11, 12, 15, 16, 23, 24, 25, and 26 show various MRI displays.

The direct-view storage tube display was very poor from the standpoint of search and mapping, and navigation. Its only use, therefore, was for a profile display (E-scan) for terrain-clearance operation. The recording storage tube was never put into operation because of lack of time.

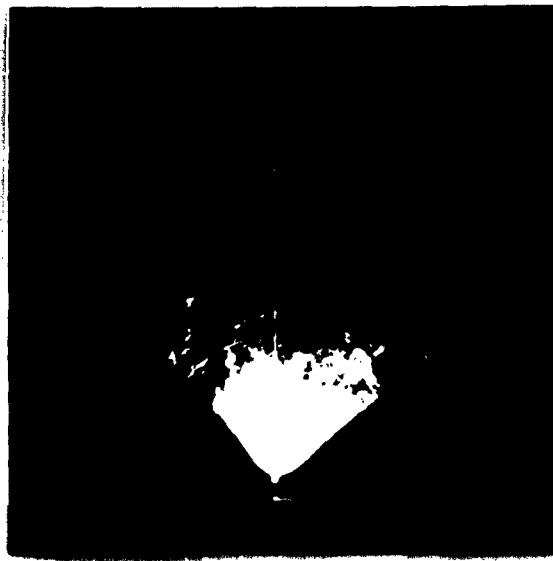
The transmitter-modulator operation and performance were very good. Magnetron reliability and life were excellent. The synchronizer seemed overly complex and consequently was difficult to align and to keep aligned. The marker generator output was switched from 1-microsecond (μ sec) to 3- μ sec markers for long-range operation and was decidedly undesirable.

Because of the poor performance of the radar during the search and mapping flight-test phase and the time required to correct the problems mentioned above, the scope of the flight-test program was never fulfilled. Sufficient time was not available to adequately evaluate the performance of the radar in terrain-clearance and track-while-scan operations, or its capability in all mapping functions. Accuracy of the radar, particularly in the Bombing-Navigation (Fix) mode, was not determined.

The series of eight photographs in Fig. 20 is presented to illustrate the display of the radar in the Bombing-Navigation mode, unexpanded, during a run-in on Treasure Island in the San Francisco Bay area. The radar cross hairs were laid on the island target at approximately 14 n. mi. (Fig. 20c), and tracking is represented to 5 n. mi. (Fig. 20c, d, e, f, g, and h).

A total of 28 flights was made. The target areas included San Diego, Los Angeles, San Francisco, and Death Valley. All flights were at 10,000 feet mean sea level (m.s.l.) with the exception of Flights 11 and 12. Figure 30 is indicative of the results of Flight 12 at 20,000 feet.

The results of the flight tests are described in the following section of this report. Table 1 is a flight record of each flight, detailing performance and post-flight maintenance. Appendix A describes the modes of operation of the radar, and Appendix B contains a functional description of the equipment.



(a) Fan beam.



(b) Pencil beam.

FIG. 5. 120-Mile Displays Showing Difference in Antenna Gain. San Luis Obispo area, heading 90 degrees; 20-mile markers, wide pulse.



(a) Fan beam.

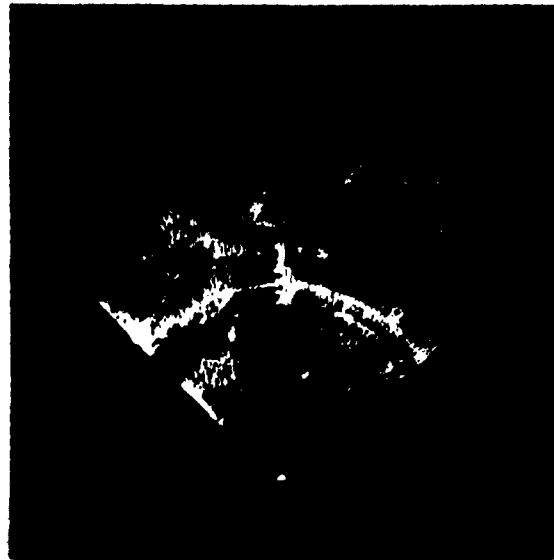


(b) Pencil beam.

FIG. 6. Displays Showing Difference in Antenna Gain Between Wide-Pulse Pencil-Beam and Fan-Beam Operation. Los Angeles area, looking south toward coastline, heading 225 degrees; 20-mile markers.



(a) Narrow pulse.



(b) Wide pulse.

FIG. 7. Comparison of Short-Range Narrow-Pulse and Wide-Pulse Displays, Mothball Fleet, San Suisun Bay. Fan beam; 5-mile markers; note distortion in wide-pulse display.



(a) Narrow pulse.



(b) Wide pulse.

FIG. 8. Comparison of Short-Range Narrow-Pulse and Wide-Pulse Displays, San Francisco Area. Fan beam; 5-mile markers; note distortion in both displays.



(a) Over La Jolla, looking south to San Diego; 5-mile markers; narrow pulse; pencil beam.

(b) Over La Jolla, looking north; 10-mile markers; wide pulse; fan beam.

FIG. 9. Displays Showing Undesirable Characteristics of Receiver Noise.



(a) Σ only.



(b) MRI.

FIG. 10. Comparison of Σ Only and MRI Operation, San Francisco Bay Bridge. Note improvement of distortion.

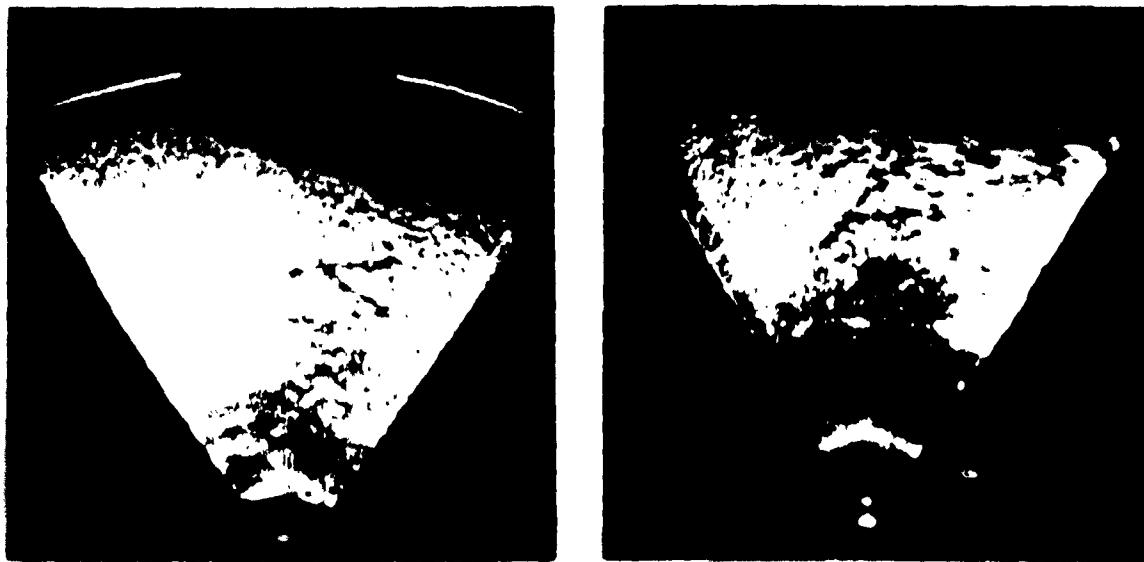


FIG. 11. MRI Displays, Naval Air Facility, China Lake. Narrow pulse; pencil beam; 5-mile markers.



(a) Σ only.

(b) MRI.

FIG. 12. Comparison of Σ Only and MRI Operation, Los Angeles Area (Long Beach). Narrow pulse; fan beam; 5-mile markers.

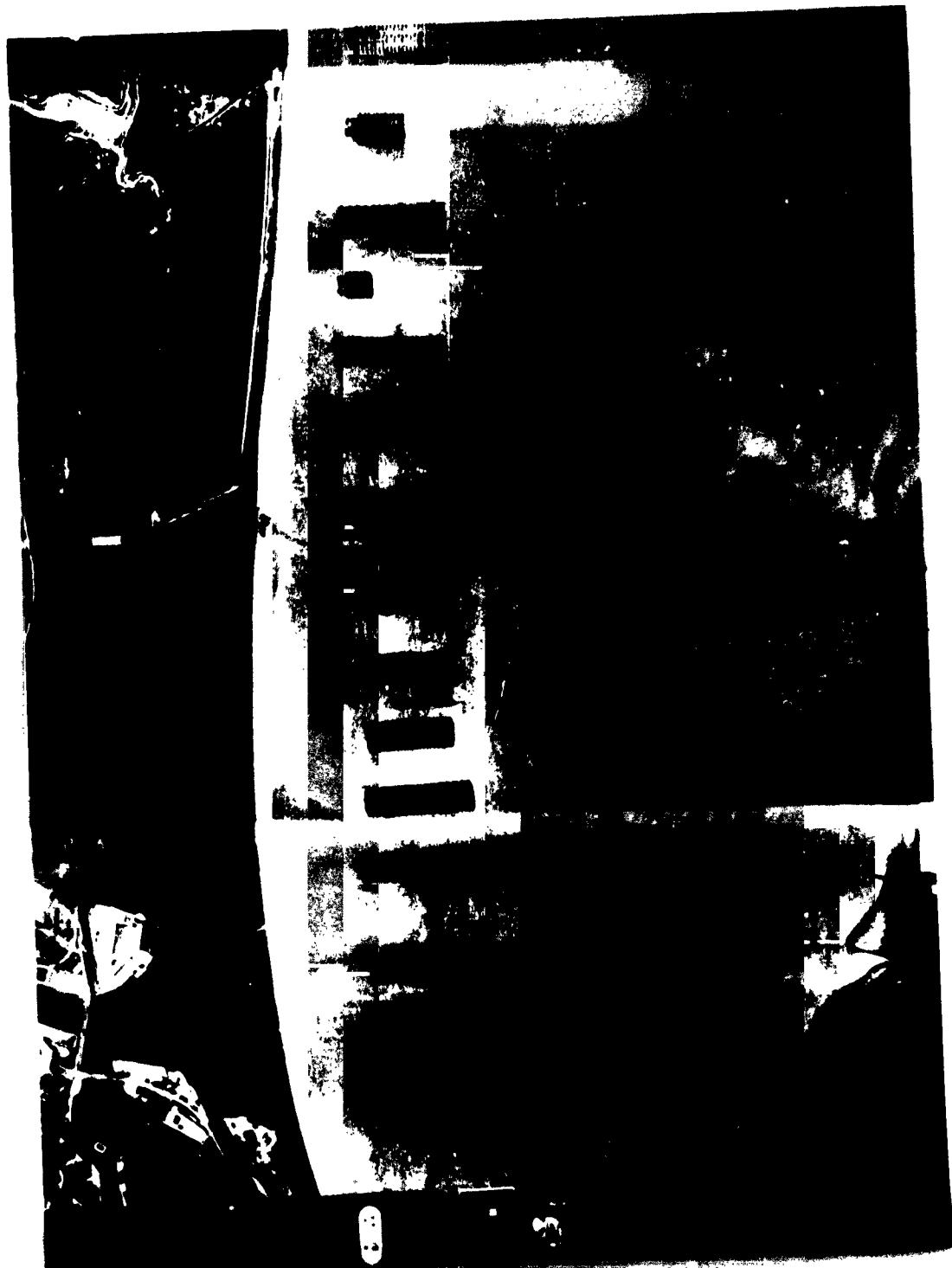


FIG. 13. Radar Target, Mothball Fleet, San Suisun Bay.

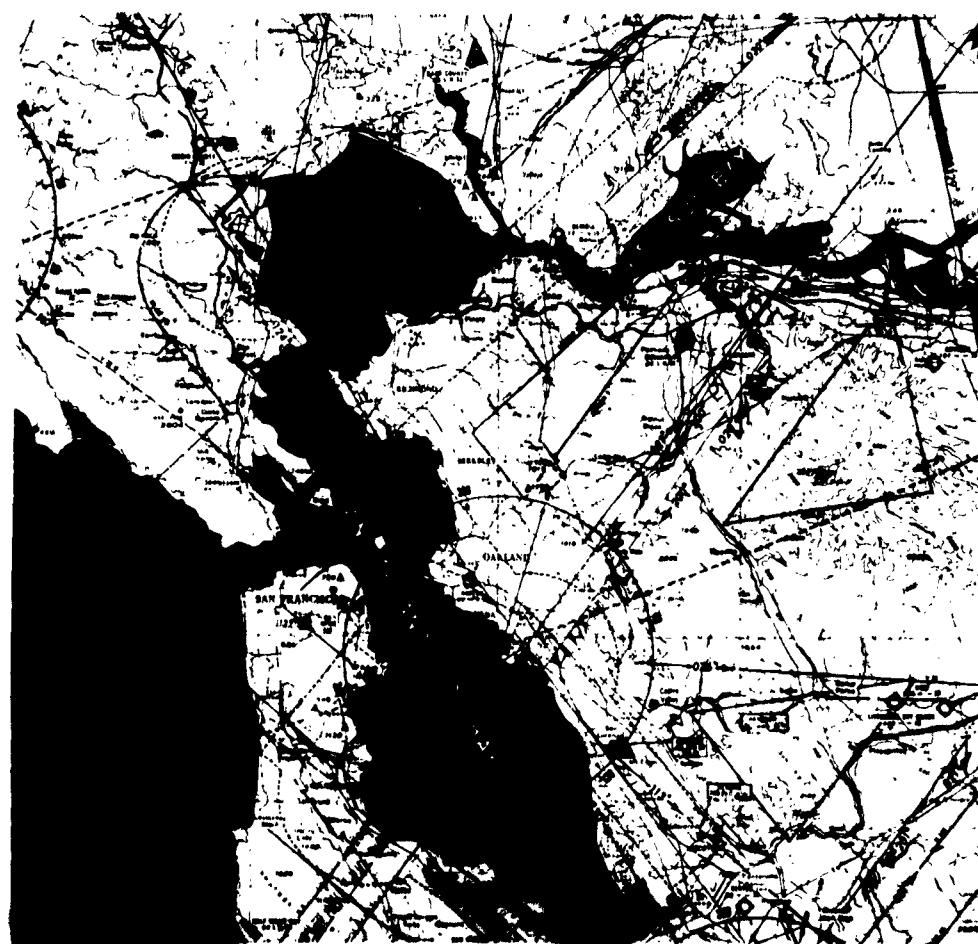
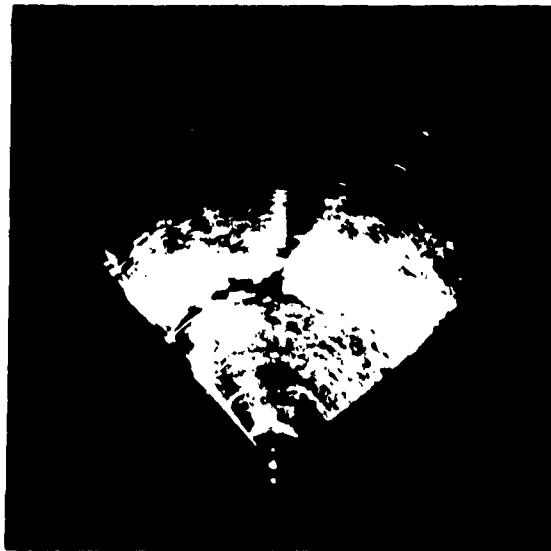
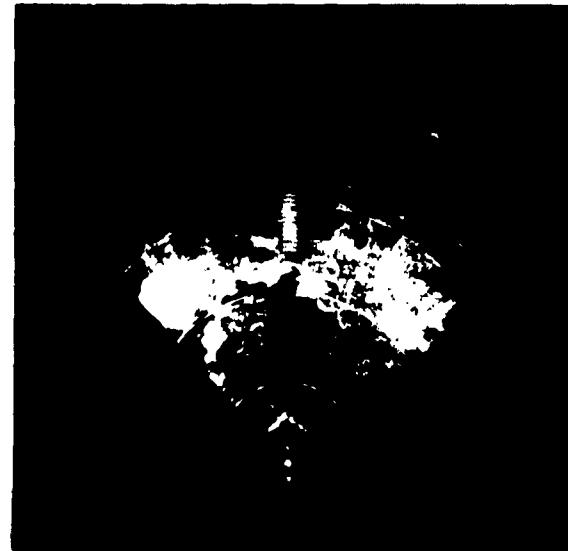
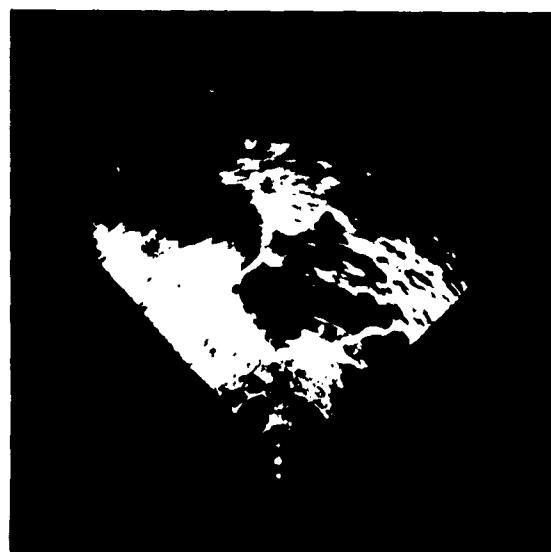
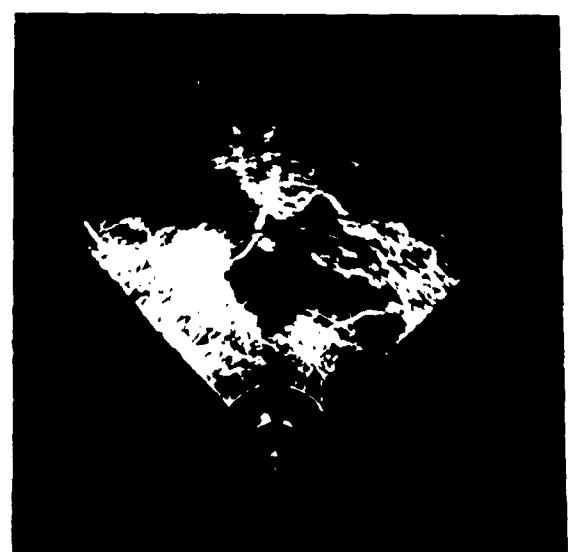


FIG. 14. Radar Target, San Francisco Area, Including San Suisun Bay.

(a) Σ only.

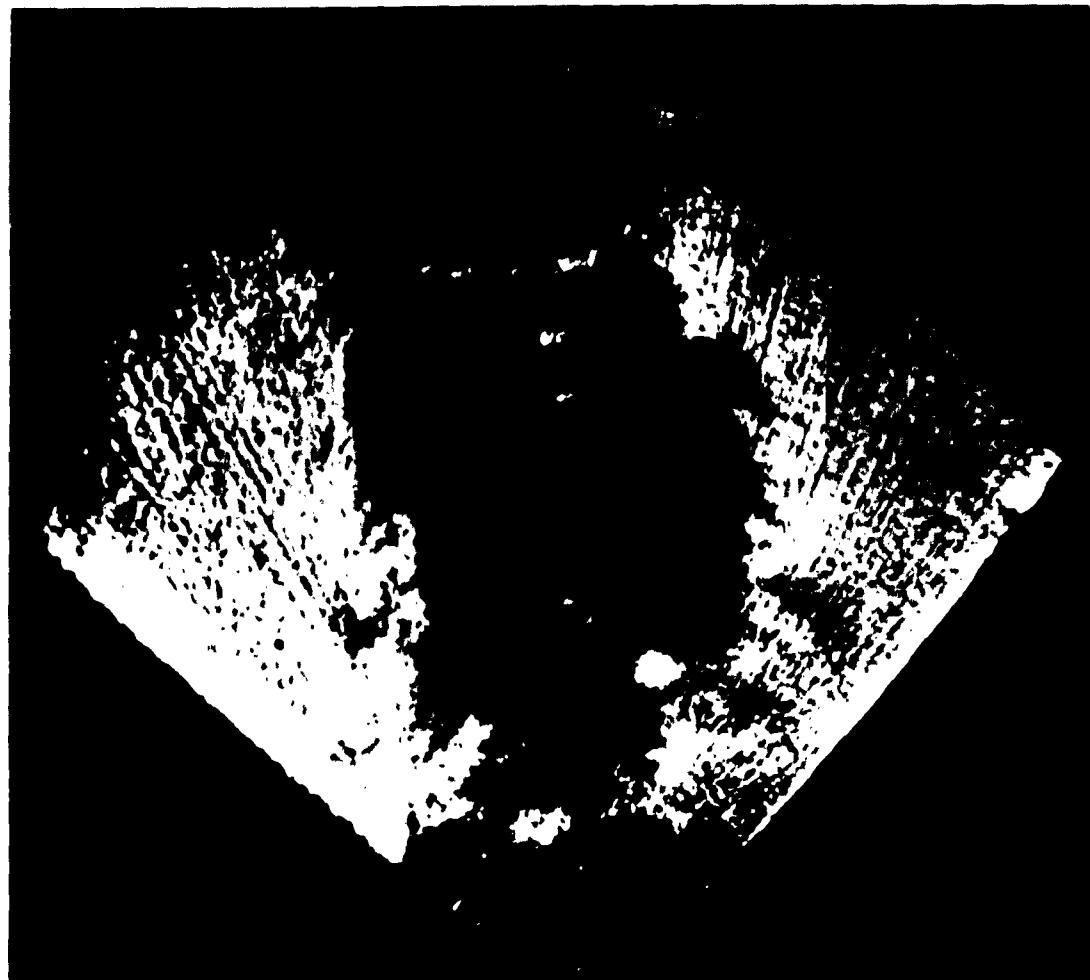
(b) MRI.

FIG. 15. Comparison of Σ Only and MRI Operation, Mothball Fleet, San Suisun Bay. Pencil beam; 5-mile markers. Note improvement of distortion.

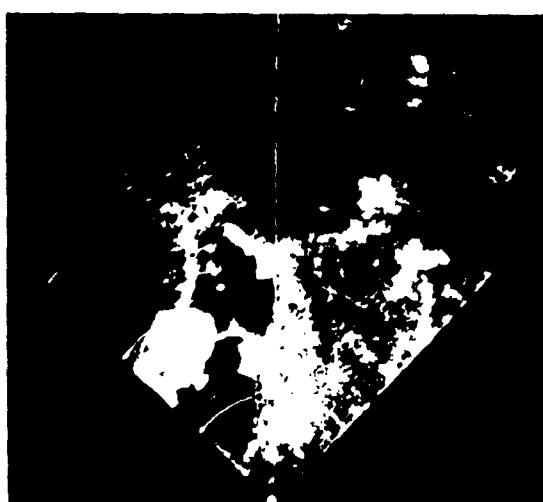
(a) Σ only.

(b) MRI.

FIG. 16. Comparison of Σ Only and MRI Operation, San Francisco Area, Showing Golden Gate Bridge, Bay Bridge, Richmond—San Rafael Bridge. Pencil beam; 5-mile markers. Note improvement of distortion.



(a) Wide pulse; 5-mile markers.

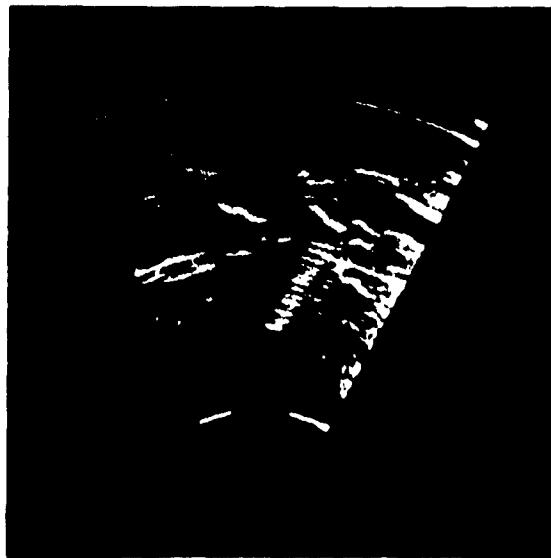


(b) Wide pulse; 10-mile markers.

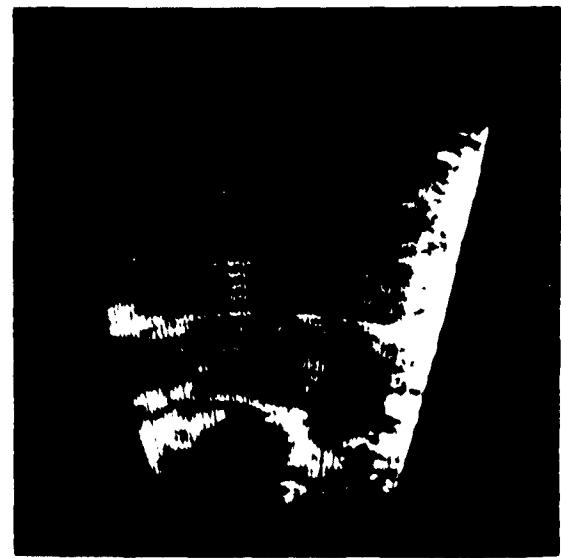


(c) Narrow pulse; 5-mile markers.

FIG. 17. Displays Showing Distortion, San Francisco Area. Fan beam.

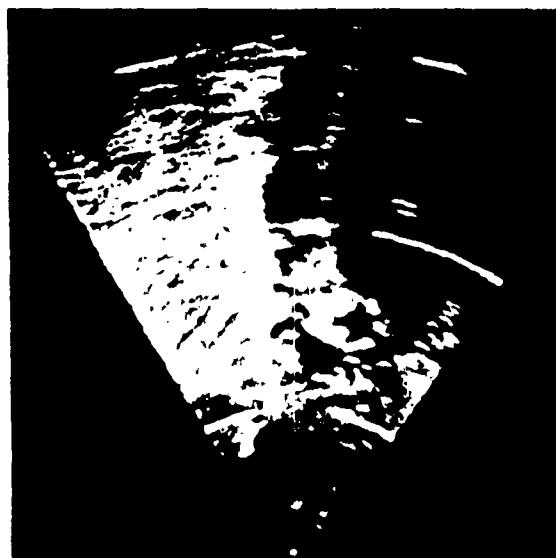


(a) Narrow pulse.



(b) Expanded display; narrow pulse.

FIG. 18. Displays Showing Distortion, Mothball Fleet, San Suisun Bay.



(a) San Diego—North Island area.

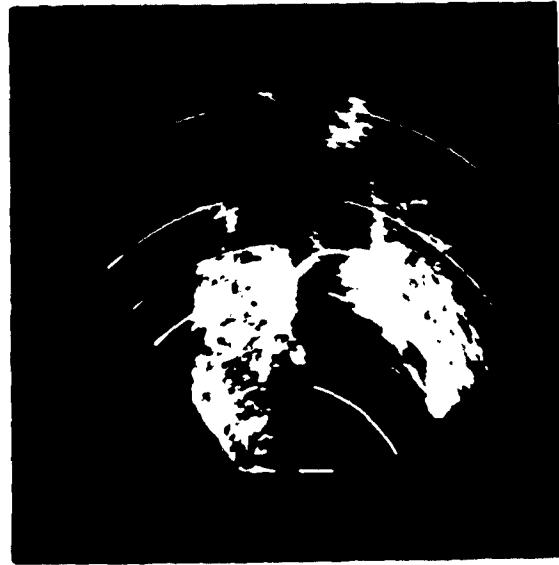


(b) Los Angeles area, showing street pattern.

FIG. 19. Displays Showing Improvement of Distortion. Narrow pulse; pencil beam.



(a) 21-mile range.



(b) 15-mile range.



(c) 14-mile range.



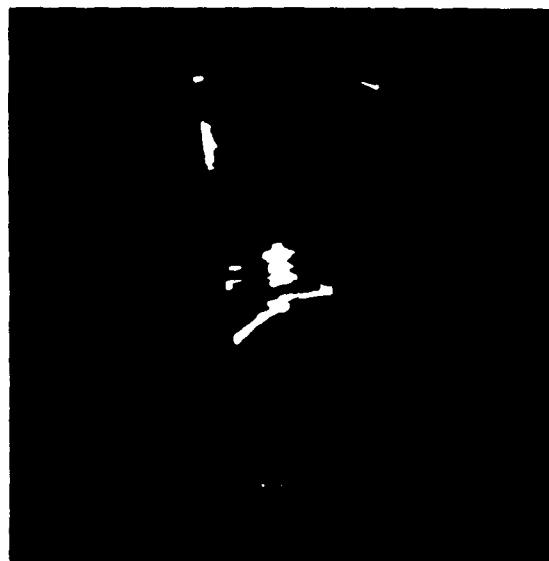
(d) 12-mile range.

FIG. 20. Bombing—Navigation Mode, Unexpanded Display; San Francisco Bay Bridge and Treasure Island. Narrow pulse; fan beam; ranges are from aircraft to Treasure Island.



(e) 10-mile range.

(f) 8-mile range.



(g) 6-mile range.

(h) 5-mile range.

FIG. 20 (Contd). Bombing—Navigation Mode, Unexpanded Display; San Francisco Bay Bridge and Treasure Island. Narrow pulse; fan beam; ranges are from aircraft to Treasure Island.



FIG. 21. Radar Target, Los Angeles Area, Including Long Beach.

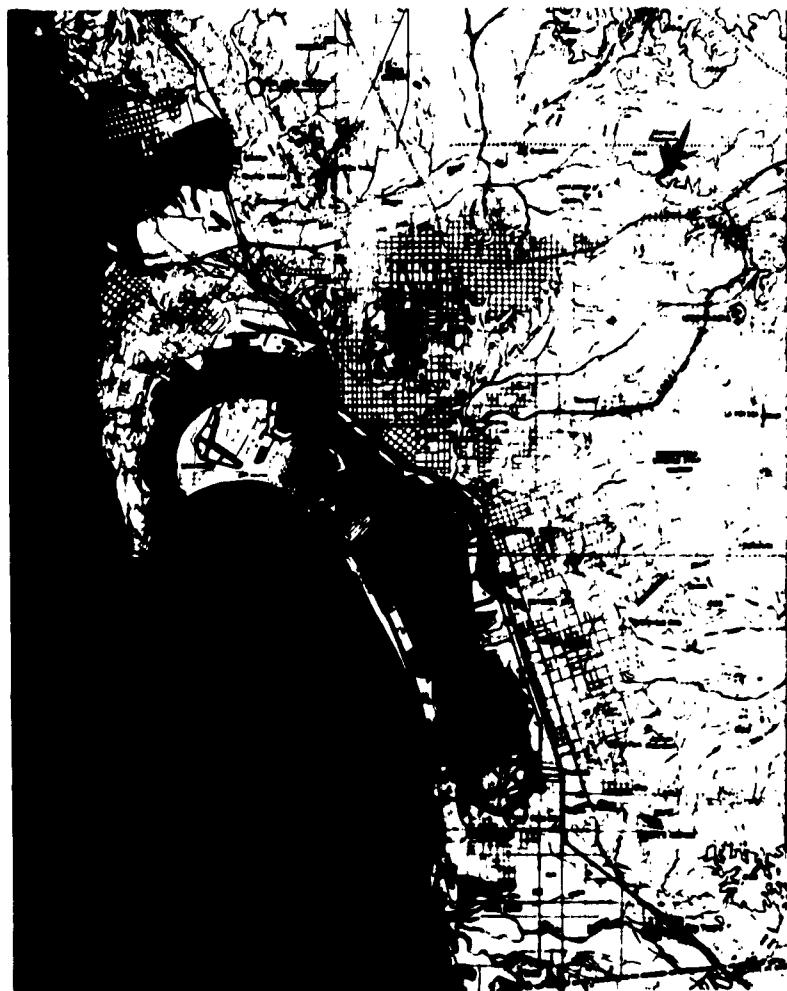


FIG. 22. Radar Target, San Diego Area.

PERFORMANCE AND MODIFICATIONS

ANTENNA ASSEMBLY

Late in the flight-test program the antenna lost pitch stabilization because of a broken lead in the bottom limit switch, necessitating removal from the aircraft for repair in the laboratory. While this was being accomplished, the bearings in the azimuth axis drive mechanism were found to be badly worn. The antenna was returned to Stavid Engineering, where new gears, as well as new bearings, were installed. Normally, repairs of this nature would not be expected in equipment that had operated only 60 to 80 hours at the test facility. It is believed that the bearings were mechanically inadequate and that this had caused inordinate wear on the gears.

The breaking of the azimuth limit switches caused the loss of scanning motion on several occasions. The switches were considered mechanically inadequate.

The azimuth drive motor burned out on one occasion and was replaced. The cause of the failure was not determined.

The only modification made to the antenna assembly that was incorporated in the developmental model was the addition of a manual tilt control. Since the flight altitudes during the testing phase were lower than the 40,000 feet for which the fan-beam pattern was optimized, it was necessary to tilt the reflector manually to evaluate the set's range capability. This was accomplished by adding a differential synchro in the depression axis servomechanism of the experimental model.

The developmental model of the radar has hydraulic servomechanisms in the roll, pitch, and azimuth axes instead of electronic servos. Hydraulic systems have a faster speed response, smoother motion, and more power for a given weight. Improved performance is expected.

TRANSMITTER-MODULATOR

The operation of the transmitter-modulator was very good except for an electrical breakdown when unpressurized, the only serious problem. The transmitter-modulator was pressurized to 18 or 20 pounds per square inch absolute to prevent electrical breakdown at high altitudes; however, unpressurized operation was to be expected during ground operation. When the case was removed for bench operation, there was severe arcing in the high-voltage power supply that resulted in the loss of the charging and inverse diodes. Recurrence of the breakdown was prevented by rerouting high-voltage leads and adding insulation where necessary.

The magnetron was replaced after a normal operating period of 200 hours. Only this one replacement was necessary during the test period.

The selector vacuum switch in the pulse package caused considerable difficulty by sticking in the narrow-pulse position, and could be released only by striking a hard blow on the case. The switch resumed normal operation after the energizing solenoid coil was replaced with one having increased ampere-turns.

The magnetron tuning drive motor used as a 208-volt motor burned out and was replaced. During the building of the developmental model, the motor was found to be rated at only 115 volts. Operating it at 208 volts had caused the overheating and eventual burnout. Resistors were added to the circuit to properly provide the motor with its rated voltage in the developmental model.

RECEIVER UNIT

In the original design, a band-pass filter was placed in series with the Σ and Δ intermediate frequency (IF) strips to change from wide-band, 8-megacycle (Mc), to narrow-band, 3-Mc, operation. Instead of increased sensitivity in narrow-band operation, which is required, the use of the filter resulted in reduced receiver sensitivity because of a 4-db insertion loss in the filter. It was necessary to remove the filter and to replace it with a tuned transformer. One stage of the pre-IF was redesigned to provide a different method of switching, and the bandwidth was controlled by loading one of the two IF stages. These changes resulted in full receiver gain during narrow-band operation.

Video Processing Unit

The video processing unit was found to be unsatisfactory in that the time constants were too great. The recovery time of the circuit did not permit passage of weak signal returns immediately after the receipt of strong signals, so there were blank areas on the indicators after the receipt of the strong echoes. The video processing unit was eventually replaced with a transistorized version having shorter time constants and therefore a more rapid recovery time. The replacement circuit designed by the contractor is used in the developmental model.

As originally designed, the video processing unit had very poor d.c. restoration. The level of the unblanking gate varied inconsistently with the length of the unblanking signal, which should have had no bearing on unblanking the indicators. The variations in the d.c. reference level were random, and were such that noise could not be displayed on the indicators under all conditions. The new transistorized version contained additional clamping diodes to provide proper d.c. restoration.

MRI Unit

The MRI circuit originally installed in the radar was purely a summing device without provisions for d.c. restoration or adequate clipping, and it caused (1) variations in the baseline level and (2) large amounts of noise from the Δ channel to appear on the navigator's indicator. Several modifications were made to the circuitry, and ground-test results are presented in Fig. 23, 24, 25, and 26.

When it became evident that minor modifications to the Stavid MRI circuitry (Fig. 23, 24, and 25) did not result in satisfactory MRI operation, a circuit was tested that was similar to that employed in the AN/APQ-71 radar (Fig. 27). This circuit used resistive adding of the Σ and Δ receiver outputs, followed by series clamping. Figure 26 illustrates the ground-test results obtained. The 2.5-kilohm ($k\Omega$) potentiometer (at A of Fig. 27) was added to adjust the relative proportions of the voltage levels of the azimuth Δ and the Σ signals. Direct-current restoration was provided by the 10- $k\Omega$ potentiometer (at B) that determined the adjustment of the bias voltage level of the diode. This circuit was used for only a few flights. It was unsatisfactory because the triple clamping arrangement required a high-level signal, and there was insufficient voltage from the IF amplifiers for efficient drive of the circuit.

The following conclusions were drawn from these tests:

1. Good MRI appears possible to ranges of about 30 n. mi. at K_u -band frequencies.
2. Good MRI requires more Δ gain (video) than Σ prior to addition; the amount of Δ gain is determined by the relation of the radio frequency (RF) Δ pattern to the RF Σ pattern.
3. Good MRI requires stable references for both Σ and Δ signals prior to addition at the video level.
4. Good MRI requires base clipping of Δ and/or clipping of the resultant signal; the former to remove excessive Δ noise, and the latter to remove negative video.
5. The Stavid video processor cannot handle large-amplitude negative signals without producing a d.c. shift in the unblanking level.

On 2 May 1960, a circuit originally developed by the Naval Avionics Facility, Indianapolis (NAFI) was installed for testing. This circuit (Fig. 28) provided an additional amplification stage in the azimuth Δ and the Σ channels. It had good amplification and better frequency response than the former circuit, but the bias level adjustment was too critical and it constantly drifted out of alignment. The adjusting potentiometer was in the nose of the aircraft, and therefore could not

be changed by the operator while viewing the indicator. The 25-k Ω potentiometer was replaced by fixed resistors and a 5-k Ω potentiometer, which permitted a finer adjustment but did not solve the initial problem. The d.c. bias level drifted beyond the range of the 5-k Ω potentiometer.

Some of the presentations had better definition when this circuit was used, but because of the drift inherent in the circuit design, the quality of the presentations fluctuated considerably.

Near the close of the flight-test period, a new circuit designed by Stavid was installed in the aircraft. This one provided added gain in both channels, which improved the total range of the radar system and therefore resulted in better definition of targets; however, the MRI action did not show significant improvement over that of other circuits used and there was no increase in resolution (Fig. 10, 11, 12, 15, and 16).

Two types of false targets appeared when the elevation MRI circuitry was used in the Terrain Clearance mode. These are termed "shadows" and "wings", and examples are shown in Fig. 32b, 33 and 34. Double targets were caused by negative overshoots in the elevation video circuits, and wings were caused by interaction between the sum and elevation difference channels. Figures 35 and 36 show the results when these effects were minimized.

Receiver Sensitivity

On early flights, the radar range was very poor. During the first flight, in pencil-beam operation only, maximum range obtained was 30 n. mi.; during succeeding flights solid painting to 40 and 45 n. mi. was obtained in fan-beam operation, and hard targets were observed to 100 n. mi. in pencil-beam operation.

Low receiver sensitivity was believed to be the cause of the short-range problem, and first efforts to increase it consisted of interchanging the IF amplifiers to obtain the highest gain for the Σ channel. Later, these amplifiers were checked for the cause of continued low gain, which was a combination of weak tubes, poor tuning alignment, and the insertion loss of the narrow-band filter.

Both the defective waveguide (see Table 1) and the insertion loss of the filter were contributing causes of the low gain. Correcting for these increased the gain by about 8 db. The preamplifiers were aligned, the tubes were checked and circuits tuned, and 1N78A microwave crystals were replaced with 1N78Bs in the Σ channel. As a result, the receiver sensitivity was eventually brought up to the design specifications.

SYNCHRONIZER

The performance of the synchronizer was good throughout the flight-test period, with only a few minor malfunctions.

During operation in the Terrain Clearance mode, the clearance line disappeared after having operated normally for the first portion of one of the test flights. It was found that there was an open winding in a pulse transformer and an intermittent short circuit in a coaxial cable. The defective transformer was replaced.

One flight was aborted because of the loss of range markers, caused by a loose transistor in the range marker generator.

A series of flights was made to test the accuracy of the track-while-scan function. The results of two representative flights are shown in Fig. 29a and b which are plots of the radar's depression-angle readout error with respect to the depression angle as computed from Askania data. Since the error increased as the radar approached the corner reflector target, it was assumed that the radar was actually locked on to a different target. The dashed line represents the theoretical error if the radar had been looking at the next target in line, which was 2,000 feet north. Since the curves seem to fit, the assumption was probably correct. The error in the depression-angle readout varies randomly for both runs. The oscillations could have been caused by instability in the antenna's pitch axis, the depression-angle servosystem, or a combination of these.

During the test program, the range scale value was changed from 6,000 feet per n. mi. to 6,076 feet per n. mi. for greater precision, as the design specification required a ranging accuracy of 0.1%.

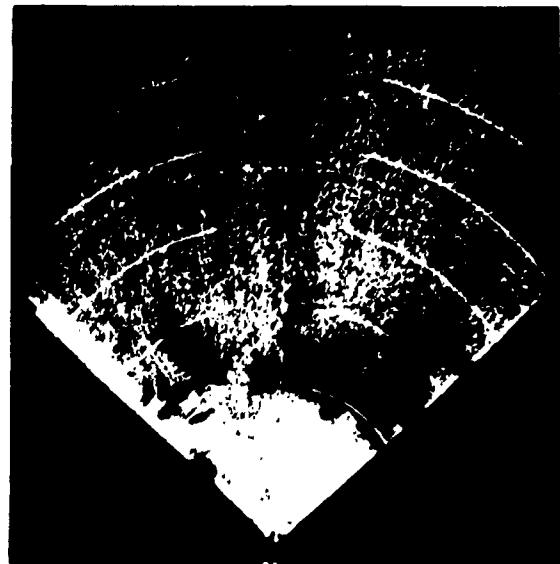
RECORDING STORAGE UNIT AND INDICATORS

The direct-view storage tube performed satisfactorily when in good adjustment but at best was unsuitable for all modes except E-scan Terrain Clearance. Any change in the gain settings of the radar receiver required a readjustment of the controls on the storage tube. The optimum performance settings were very critical and difficult to keep in adjustment for this reason. Too little video gain or storage time resulted in a complete loss of weak targets or a fadeout of the display, and too much gain and high storage time resulted in excessive blooming. Since a depressed-center plan position indicator (PPI) display was used for mapping, it would seem desirable to use a time-varying video pedestal to provide more uniform illumination over the sector and to reduce blooming at the apex.

The navigator's indicator performed satisfactorily after modifications to reduce noise pickup and video distortion were made to the

circuitry. To eliminate difficulties encountered with the presentation, insulation was added and certain leads were rerouted. These problems, unfortunately, were not adequately resolved until near the end of the flight-testing period.

The recording storage unit (RSU) was not evaluated because of a lack of time.

(a) Σ only, maximum gain.(b) Δ only, maximum gain.(c) Maximum Σ gain, Δ adjusted for best apparent MRI.

(d) MRI with sacrifice of sensitivity.

FIG. 23. Comparison of Ground-Test Displays Before Changes to MRI Circuitry.

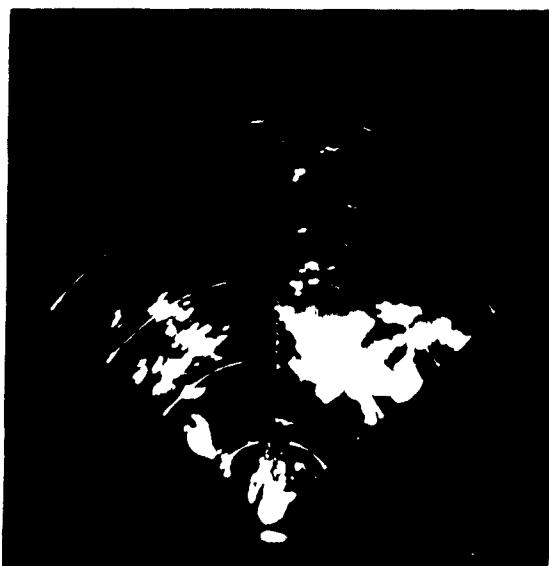
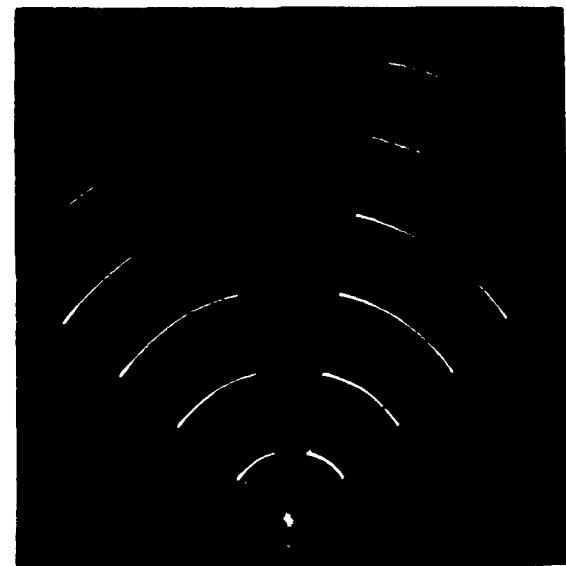
(a) Σ only, maximum gain.(b) Δ only, maximum gain.(c) Maximum Σ and maximum Δ .(d) Maximum Δ , lower Σ gain.

FIG. 24. Comparison of Ground-Test Displays Following Addition of Series Clipper to MRI Circuit. Note elimination of noise in (b) as compared with 23(b); note loss of sensitivity in (c) and (d).

(a) Maximum Σ , no Δ .(b) Maximum Δ .(c) Maximum Σ and maximum Δ .(d) Maximum Δ , Σ gain reduced.

FIG. 25. Comparison of Ground-Test Displays Employing Elevation MRI Circuit in Azimuth With Series Clipper. Note increase in noise in (c) and loss of sensitivity and poor MRI in (d).

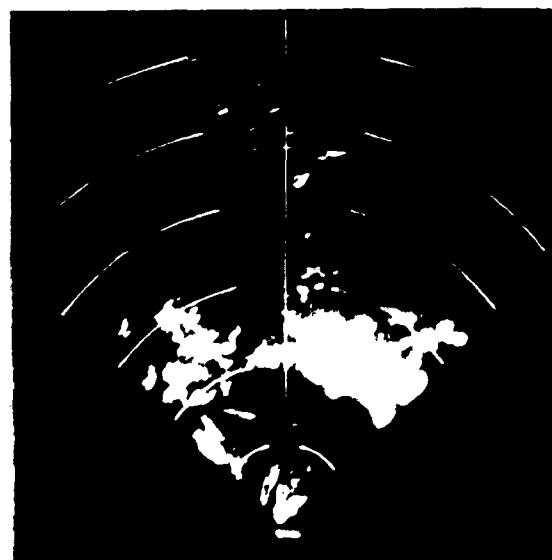
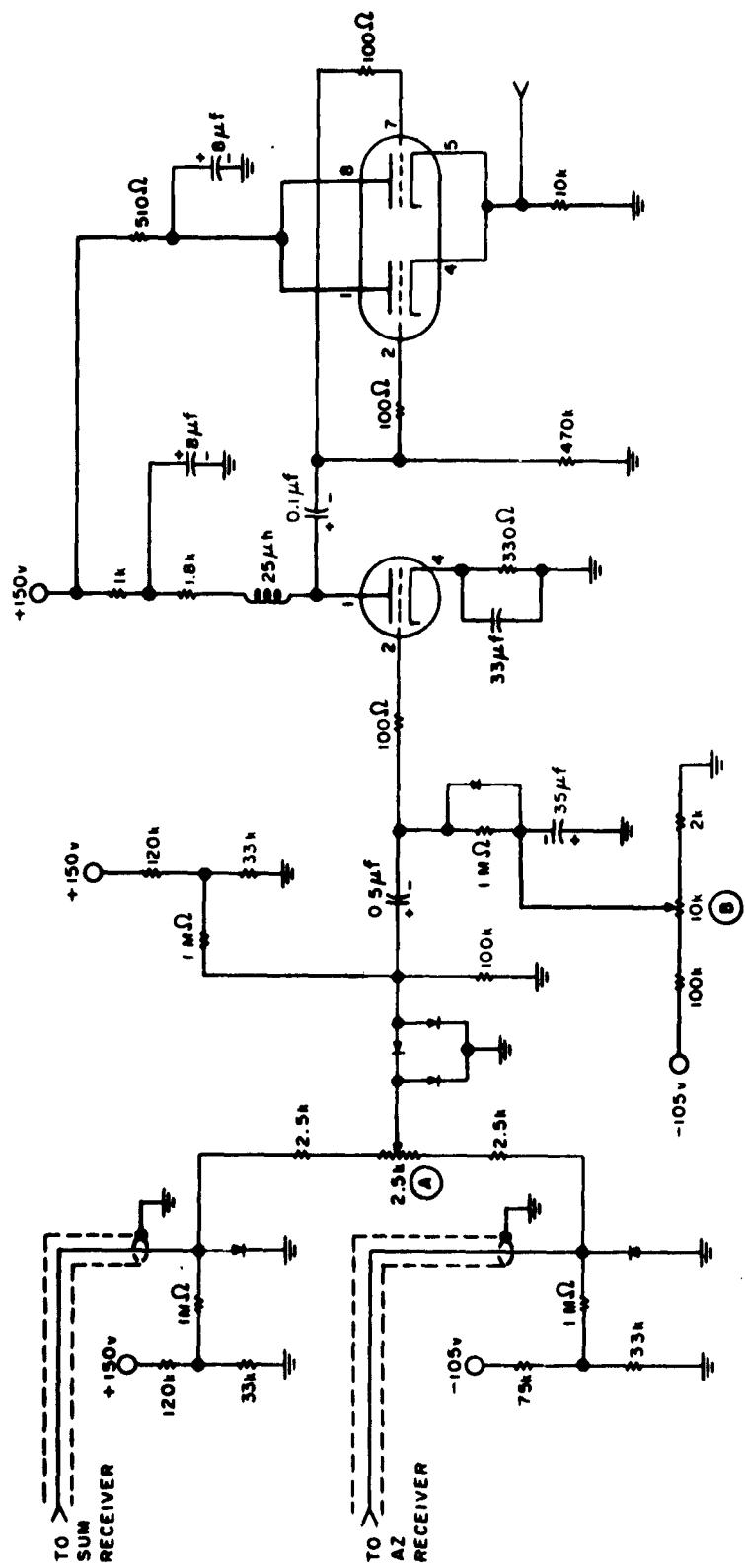
(a) Maximum Σ .(b) Maximum Δ .(c) Maximum Σ and maximum Δ .(d) Maximum Σ and maximum Δ .

FIG. 26. Comparison of Ground-Test Displays Employing MRI Replacement Circuit of Fig. 27. Note slight improvement in sensitivity in (d).



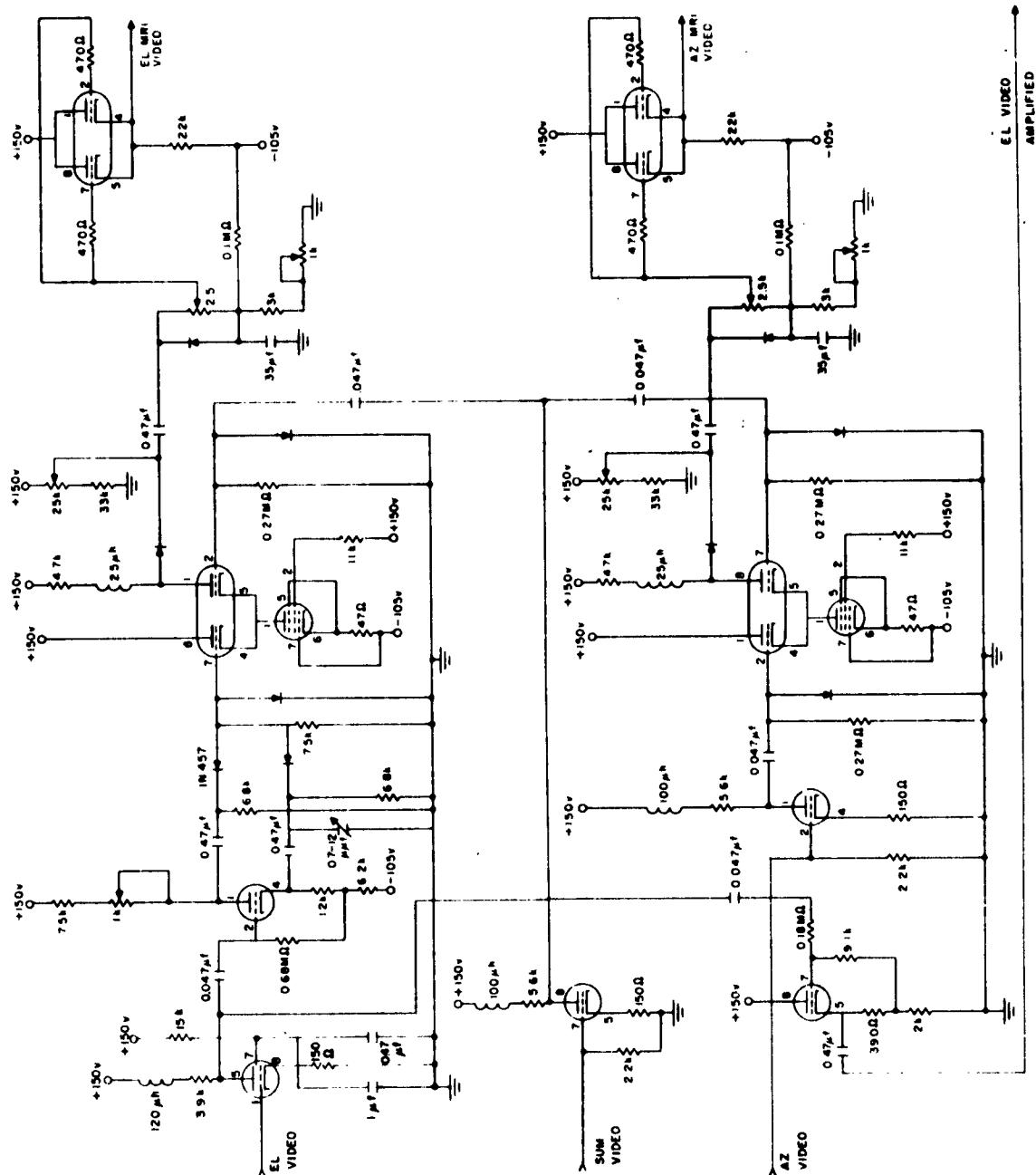
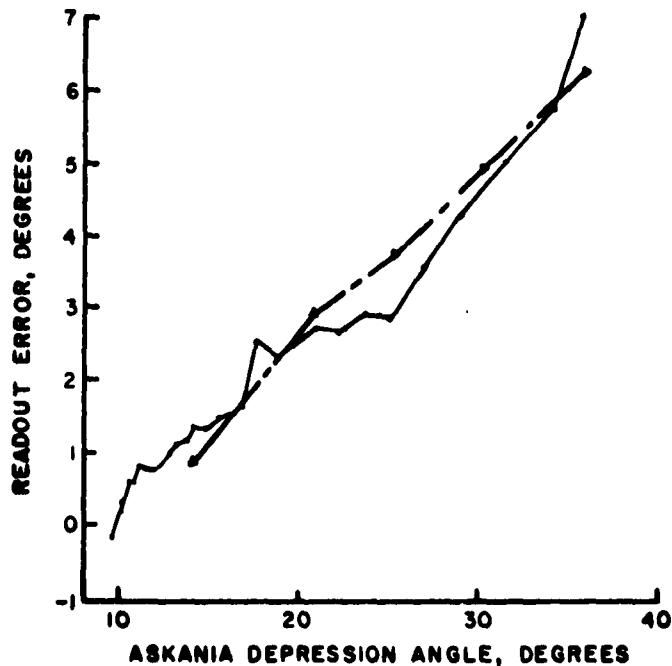
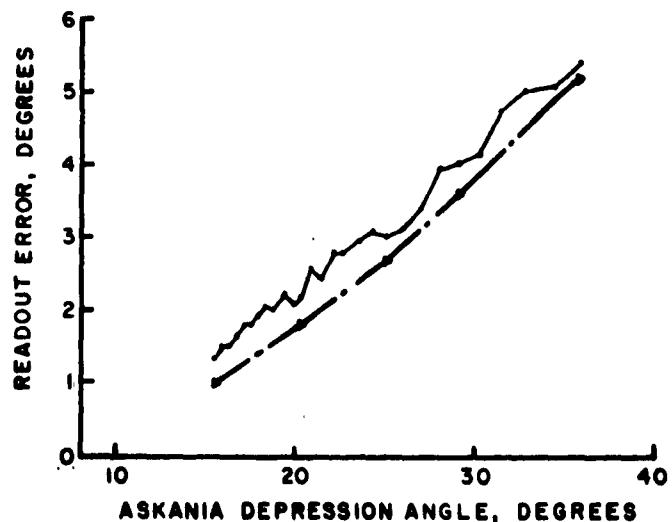


FIG. 28. NAFI-Developed MRI Circuit.



(a) Flight 26, Run 4.



(b) Flight 26, Run 7.

— Actual radar depression-angle error.
- - - Computed curve for target 2,000 feet north.

FIG. 29. Depression-Angle Readout Error Versus Askania Depression Angle.

TABLE 1. Radar Set Group OA-2003(XN-1)/ASB Flight Record—
Performance, Maintenance, and Corrective Measures

Flt. No.	Date	Comments ^a
1	24 Nov 59	SFO. Radar performance was poor; the maximum range was 30 n. mi. in pencil-beam operation. The flexible waveguide between the transmitter and the antenna cracked, and the AFC failed.
2	4 Dec 59	Maintenance. The waveguide section was replaced. A new AFC unit was installed and the old one, which was found to have a bad tube, was repaired.
4	Dec 59	LAX. There were no equipment failures on this flight, but maximum range was poor, as on the first flight.
3	17 Dec 59	Maintenance. The transmitter and receiver were checked to determine the cause of poor range. The transmitter power output was adequate, but the gains in the receiver IF amplifiers were well below design specifications. Without pinpointing the reasons for the low gain, the identical IF amplifier units were interchanged in order to have the highest gain in the Σ channel of the receiver.
4	22 Dec 59	LAX. Radar range improved, resulting in solid painting to 40 n. mi. and isolated targets to 60 n. mi., but these ranges were still less than expected.
		Maintenance. Work continued on the receiver after the flight.
		LAX. The best ranges to date were obtained on this flight; solid painting to 45 n. mi. and isolated targets to 100 n. mi.

^aFlight routes (maps and photographs of areas are shown in Fig. 13, 14, 21, and 22)
 SFO, San Francisco
 LAX, Los Angeles
 SAN, San Diego

TABLE 1. (Contd.)

Flt. No.	Date	Comments
		Maintenance. The Displacement Gyroscope CI-100 was installed in the aircraft to provide antenna stabilization. Prior to this, the antenna had received pitch and roll signals from hand-set synchros installed as a temporary measure.
5	31 Dec 59	LAX. Trouble was encountered with the sweeps, azimuth line, and the AFC unit. The maximum ranges were less than on flight 4.
		Maintenance. The system was taken to the shop for repair after the flight. Realignment of the sweep generator circuits corrected the sweep trouble. The disappearance of the azimuth line was caused by a loose connector, and the AFC trouble was caused by a bad tube and a defective balancing potentiometer. The decrease in range was due to the fact that the operator no longer had control of the antenna tilt, since the pitch control was coming from the CI-100 gyroscope. Since the fan beam of the antenna had been optimized for 40,000 feet above the terrain, some tilt control was necessary to increase the range at lower altitudes. A tilt control also enabled the operator to aim the pencil beam at a desired target without going to the <u>Fix</u> mode of operation. A differential synchro was added to the depression axis servo to give the operator control of the antenna tilt during flight. Also, in the <u>Search</u> mode, a switch permitting selection of either pencil or fan beam was incorporated.
6	8 Jan 60	LAX. The flight was aborted shortly after takeoff when the antenna stopped scanning.
		Maintenance. The antenna malfunction was caused by a bad connection in one of the aircraft cables which was repaired. A broken lead to the antenna azimuth limit switch was also replaced.
7	12 Jan 60	LAX. The radar range was about equal to that of Flight 4; no improvement was discernible. Noisy spots on the variable range sweep control potentiometer that were gradually getting worse had now reached the intolerable stage.

TABLE 1. (Contd.)

Flt. No.	Date	Comments
		<p>Maintenance. After the flight, the entire set was taken into the shop. Additional engineering support arrived from Stavid Engineering. The variable range sweep control was replaced. The flexible waveguide in the antenna pitch axis was defective (4.5-db loss) and was replaced. The post-IF amplifier (Σ channel) had low gain due to a weak tube and was repaired. The filter used to provide narrow-band IF with wide-pulse operation was replaced with a tuned transformer, resulting in a gain increase of 3 db. The transmitted spectrum was showing signs of deterioration. Although the power output was adequate, the old magnetron with 200 hours of operation was replaced with a new one.</p>
8	29 Jan 50	<p>LAX, SAI. Radar performance was much improved. Shortly after takeoff and before the transmitter quit in wide-pulse operation, isolated targets to 120 n. mi. were observed. During the rest of the flight the radar was operated in narrow-pulse transmission only. This was the first flight made with the Beattie camera in operation to record the display.</p> <p>Maintenance. The transmitter-modulator unit and the receiver were removed from the aircraft after the flight. The transmitter was removed from its pressurized case to determine the cause of the failure to operate in the wide-pulse position. The vacuum switch in the pulse package was the source of the trouble. The switch was "hanging up" in the narrow-pulse position; i.e., the transmitter was operating with a pulse width of 0.25 μsec and a PRF of 300 pulses per second (pps), a useless combination. The switch could be made to operate by striking the transmitter case with a hard blow. Operating the transmitter-modulator unpressurized on the bench produced severe arcing among the high-voltage components, resulting in the loss of both the inverse and charging diodes.</p> <p>Rerouting high-voltage leads and the placement of insulating material prevented the arcing and its costly results. The internal cooling blower developed defective bearings and was replaced.</p>

TABLE 1. (Contd.)

Flt. No.	Date	Comments
9	9 Feb 60	The video processing circuit was replaced with the transistorized version designed for the developmental model. The recovery time was too great with the old circuit; blank spaces appeared after strong returns from close targets. Rather than rely on the Sensitivity Time Control (STC) to reduce the effect, the old circuit was replaced with a circuit having shorter time constants, which corrected the trouble.
10	16 Feb 60	This was primarily a doppler radar calibration flight. The Stavid radar was used only for operator training, and no data were taken.
-	10 Mar 60	This flight had the best range results to date. Solid painting was observed to 80 n. mi. and isolated targets to 120 n. mi., the maximum range for which the radar was designed. The vacuum switch in the pulse package again caused trouble and had to be pounded occasionally to obtain wide-pulse operation.
11	15 Mar 60	A series of tests was conducted at the flight line with the old MRI unit and a new breadboard unit (similar to that of the AN/APQ-71 radar).
12	18 Mar 60	This was intended as a flight at 20,000 feet over the San Francisco Bay area; however, the range markers went out shortly after takeoff and the flight was canceled. The pilot took the aircraft to 20,000 feet and checked its performance at the higher altitude. Several photographs were taken of the presentation without range markers while at this altitude over desert terrain.
		Maintenance. The loss of the range markers was caused by a loose transistor in the range generator oscillator. A holding spring had not been snapped into place, and this allowed the transistor to shake loose.
		SFO. This flight was made at 20,000 feet over the Bay area (Fig. 30). The weather was clear except for a slight haze over the city. Radar returns were good on all legs of the trip except the return when there was a loss of

TABLE 1. (Contd.)

Flt. No.	Date	Comments
		sensitivity and an increase in noise on the indicator in the form of streaks or flashes.
		Maintenance. The cause of the loss of sensitivity could not be determined, since everything appeared to be working normally during ground checks. The indicator noise appeared when the depression axis of the antenna was moved.
13	24 Mar 60	This flight was to check performance in the <u>Terrain Clearance</u> mode (Fig. 31 and 32). Six runs were made on <u>Telescope Peak</u> (11,049 feet) in the Death Valley area with the aircraft flying at 10,000 feet m.s.l. Two types of false targets appeared when using MRI in the <u>Terrain Clearance</u> mode. These are termed "shadows" (double targets) and "wings," examples of which are shown in Fig. 32b, 33, and 34 (discussion on page 25).
-	25 Mar 60	This was an inertial system test flight. The radar was operated to determine whether or not sensitivity loss would occur. The loss in sensitivity did occur and a drop was noted in the klystron local oscillator voltage and current.
14	-	Maintenance. The voltage drop was caused by a bad transistor in the regulator of the 300-volt receiver power supply. Repairing the receiver power supply also cleared up some of the noise streaks that were previously present. Clamping in the elevation MRI eliminated the problem of the double targets.
15	31 Mar 60	LAX. This flight was aborted shortly after takeoff when the antenna lost pitch stabilization.
		Maintenance. The loss of pitch stabilization was traced to a broken lead on the bottom limit switch. A bearing on the azimuth axis drive on the antenna was completely worn out. The radar system was removed from the aircraft and taken to the laboratory. New bearings and new gears were installed on the azimuth drive. Faulty grounding and shielding was found to have caused the noise on the sweeps.

TABLE 1. (Contd.)

Flt. No.	Date	Comments
15	2 May 60	Rerouting, careful grounding, and additional shielding of leads in the navigator's indicator eliminated much of the noise pickup. The aircraft was grounded until 2 May for engine maintenance.
16	5 May 60	This local flight was canceled 25 minutes after takeoff because of engine trouble. The track-while-scan looked good during a short check except for some mechanical overshoot of the antenna during the initial lock-on. Operation of the spoiler seemed sluggish.
17	6 May 60	Maintenance. The spoiler problem was caused by a faulty capacitor in the phase-shifting winding of the spoiler drive motor. A new NAFI-developed MRI circuit was installed.
18	24 May 60	SFO. On this 4-1/2-hour flight to the Bay area, a few terrain-clearance pictures were taken while crossing the Sierra Range, and the MRI looked good in this mode but was unstable. Several pictures of the radar presentations were taken over the Bay area, but the radar was not working well in the Mapping mode. The receiver sensitivity was down and there was considerable waviness on the expanded presentations.
		Maintenance. Previous trouble with the vacuum switch was remedied by substituting a new coil with increased ampere-turns. The MRI circuit was reworked to give better frequency response. The indicator was again reworked to remove noise pickup.
		This was an inertial navigation flight of 4-1/2 hours to Gila Bend, Arizona, and return.
		LAX, SAN. The radar presentation of the Los Angeles area looked very good; this was the first flight on which city streets were discernible in a city complex (Fig. 19).

TABLE 1. (Contd.)

Flt. No.	Date	Comments
19	25 May 60	Death Valley, LAX, SAW. This was a 4-hour flight to check the <u>Terrain Clearance</u> and <u>Mapping</u> modes. Except for losing the 1,000-foot clearance line at the beginning of the flight, the terrain-clearance results were good (Fig. 35). In the <u>Mapping</u> mode the definition over Los Angeles was not as good as on the previous flight. The range lines went out but came back after the transistors on the range line generator board were reseated (Fig. 12).
-	27 May 60	Maintenance. The azimuth channel IF amplifier stopped working because of a bad 5636 tube, and was replaced with a spare amplifier.
-	6 Jul 60	The scheduled flight was canceled because of a loose propeller blade on the aircraft. Continuous trouble with the aircraft kept it grounded until the flight of 6 July 1960.
20	8 Jul 60	Maintenance. During a ground check of the radar, the 1,000-foot clearance line disappeared. The trouble was traced to an intermittent pulse transformer. The Σ channel LN78A crystal mixers were replaced with a pair of LN78BS to improve sensitivity.
21	8 Jul 60	SFO. Good radar performance was found to be a function of the adjustment of the clipping level of the MRI unit. The clipping level was extremely difficult to adjust, and drift made it impossible to hold the correct level for a reasonable period. Solid painting to 100 n. mi. and hard targets to 120 n. mi. were observed while the clipping level was in correct adjustment. The MRI looked improved in both the <u>Terrain Clearance</u> (Fig. 36) and <u>Mapping</u> modes.
		Death Valley, LAX. This was a 3-hour flight to test the <u>Terrain Clearance</u> mode in the Death Valley area and the <u>Mapping</u> mode over the Los Angeles area. The terrain-clearance presentations looked good. Side-lobe returns were noticed while flying low through the mountain passes. The definition over the Los Angeles area in the <u>Mapping</u> mode was not as good as that of Flight 18.

TABLE 1. (Contd.)

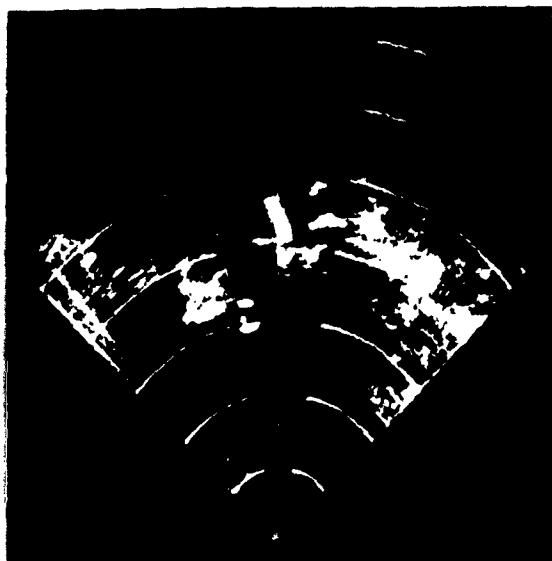
Flt. No.	Date	Comments
		Maintenance. The 25-k Ω clipping level adjustment potentiometer in the azimuth MRI unit was replaced with fixed resistors and a 5-k Ω potentiometer to allow a finer adjustment in setting the clipping level. The Σ channel crystal mixers were replaced with a pair that showed better balance.
22	12 Jul 60	SFO. This flight was to test the expanded presentation with Treasure Island as the target. Doppler-derived groundspeeds were hand-set into the computer to cause the range line to track the target. Radar performance was poor. The AFC would not work in the high PRF (1,200 pps), there was considerable distortion on the range markers, there was no signal in the elevation Δ channel, and the azimuth scan on the antenna quit on the return trip.
		Maintenance. The AFC had drifted off frequency and was realigned. The burned-out azimuth drive motor and the broken right azimuth limit switch were replaced, and a broken lead between the preamplifier and the azimuth Δ IF amplifier was repaired. The negatives from Flights 21 and 22 were black; apparently the camera had been loaded with exposed film. Test shots were taken with fresh film and the camera operated properly.
23	18 Jul 60	SAN. This flight was primarily an inertial navigation flight. The radar was operated long enough to determine the nature of its performance after the recent repairs. The set worked satisfactorily.
24	22 Jul 60	SFO. This was a 4-hour flight in the San Francisco area to test the <u>Bombing-Navigation</u> mode (Fig. 20). The runs were made on Treasure Island from <u>about 40 miles out</u> , using MRI which was not very effective. The over-all radar performance was good except for that of the MRI. The radar tracked well with doppler groundspeed values hand-set into the computer.
25	26 Jul 60	The purpose of this local 2-hour flight over the High-Altitude Bombing Range (HABR) was to make practice runs over the range for target familiarization, to

TABLE 1. (Contd.)

Flt. No.	Date	Comments
26	27 Jul 60	<p>check instrumentation, to check coordination with the range ground stations, and to test the radar's performance. All phases of the test produced good results.</p>
26	27 Jul 60	<p>HABR. Fifteen passes were made to determine the accuracy of the radar's depression-angle readout in the fix mode. Data obtained from Askania ground cameras gave the depression angle to the target at 1-second intervals during each pass. The depression-angle output of the radar was continuously recorded on an oscilloscope during each pass. A timing signal was sent from the aircraft to the ground stations to synchronize the aircraft and ground-station timing. The average aircraft altitude was about 8,400 feet m.s.l., and the target was at 2,335 feet m.s.l. The radar tracked the target well between depression angles of 10 and 50 degrees, corresponding to slant ranges between 34,500 feet and 5,100 feet at the altitude flown. Although the plot of radar-derived depression angle versus time compared closely with the shape of the theoretical curve, the magnitude of the error increased with time and was quite large close to the target (see discussion, page 26).</p>
27	18 Aug 60	<p>Maintenance. The MRI unit was replaced. Range markers were missing but came back after the transistors on the marker board were reseated. The range line from the computer was in error, caused by a misalignment in the servo repeater unit.</p>
27		<p>This was intended as a low-altitude flight up the San Joaquin Valley, but pitch stabilization went out. The pilot and copilot ran Ground Controlled Approach (GCA) landings at Palmdale. The hand control for antenna tilt was used while pictures were being taken during the approaches. The radar presentations looked good.</p>
27		<p>Maintenance. A broken lead in the cable to the pitch and roll conversion box servo was found to have caused the loss of pitch stabilization and was repaired.</p>

TABLE 1. (Contd.)

Flt. No.	Date	Comments
28	2 Sep 60	A low-altitude mapping flight was made from Buena Vista Lake to Los Banos; the radar presentations looked good at low altitude. No photographs were taken on the first part of the trip because of a camera malfunction. The flight continued on to San Francisco, and pictures were taken of the mothball fleet. The AFC was not centered during the latter part of the flight, and the range markers went out at about the same time. This flight terminated the test program.



(a) 22-mile range.



(b) 13-mile range.



(c) 9-mile range.

FIG. 30. Displays from 20,000 Feet. Mothball fleet; fan beam; narrow pulse; 5-mile markers.

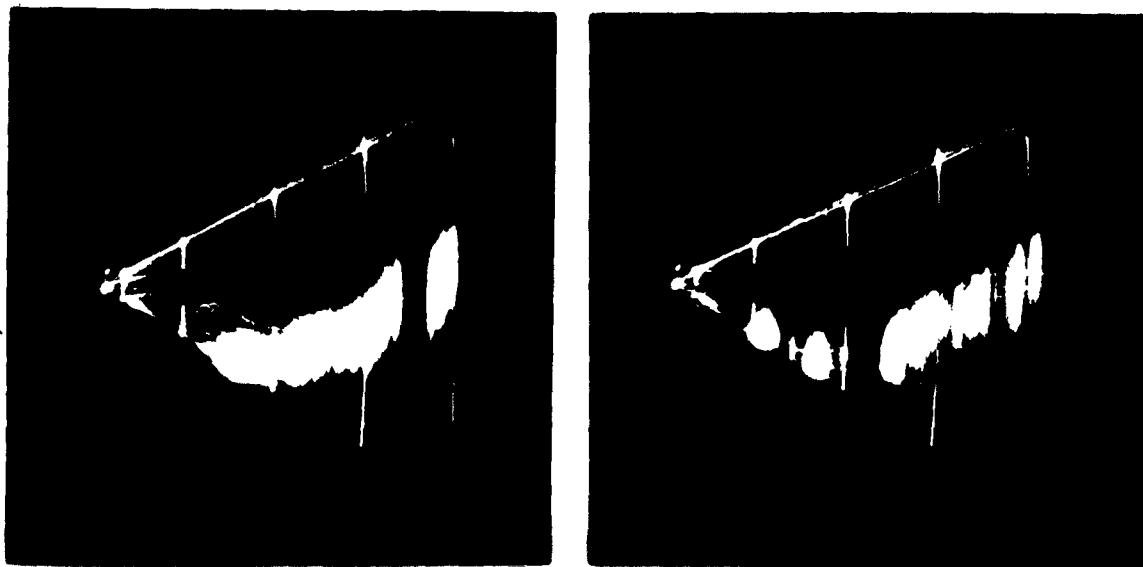


FIG. 31. Terrain Clearance, Range Height Indicator. Five-mile markers; Σ only.

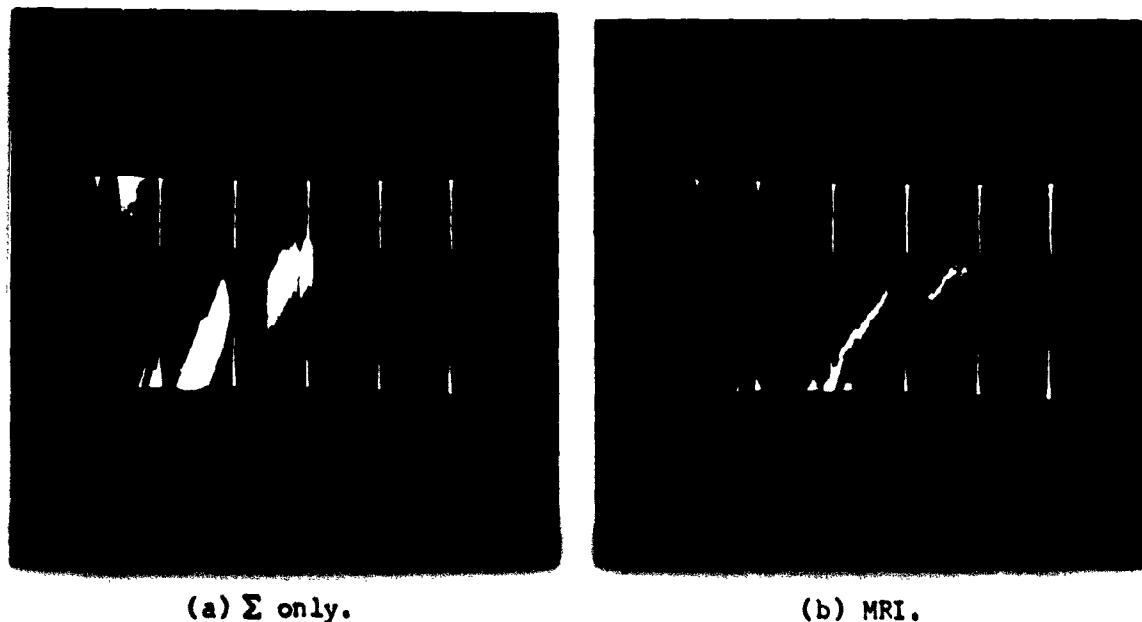


FIG. 32. Terrain Clearance, E.Scan. Two-mile markers.



FIG. 33. False Targets, "Shadows".

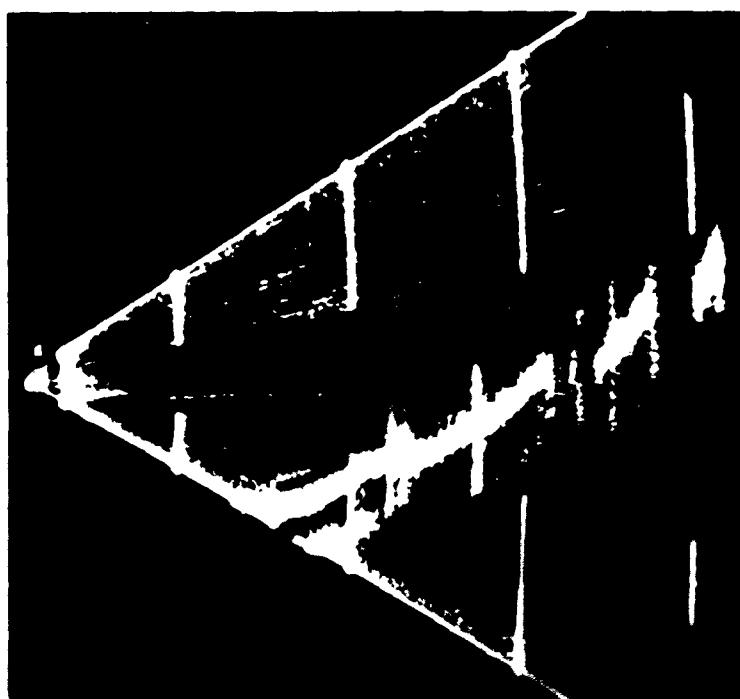
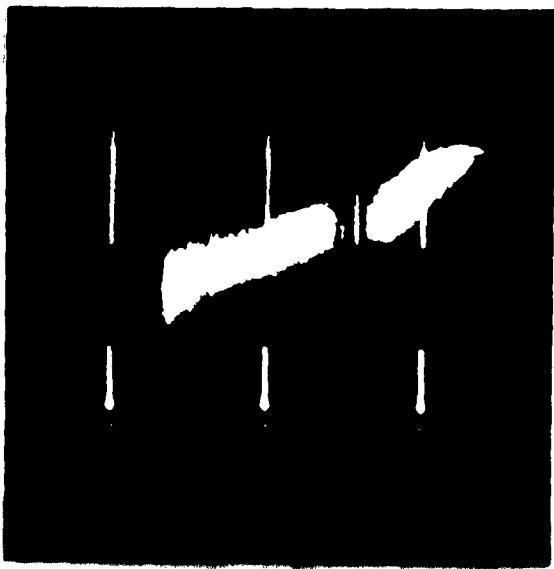
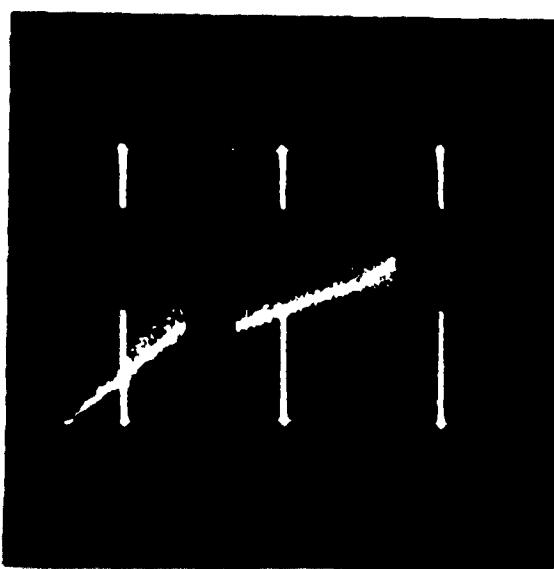
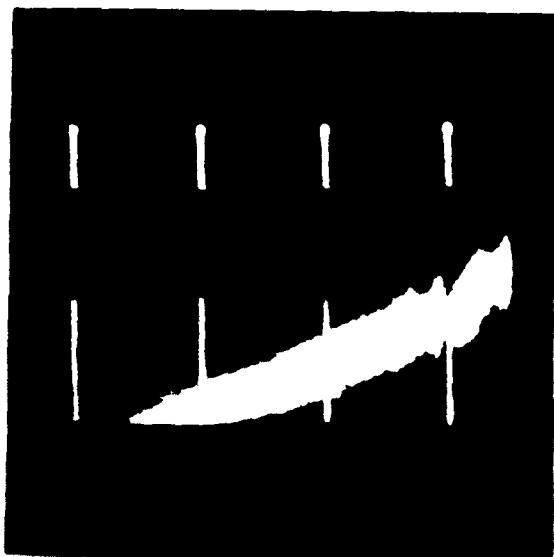
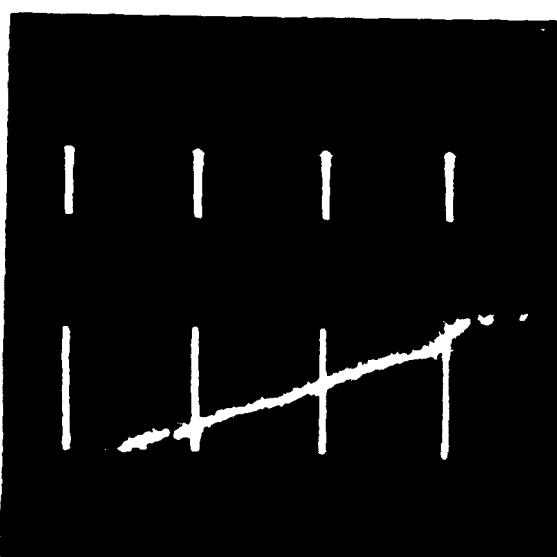


FIG. 34. False Targets, "Wings".

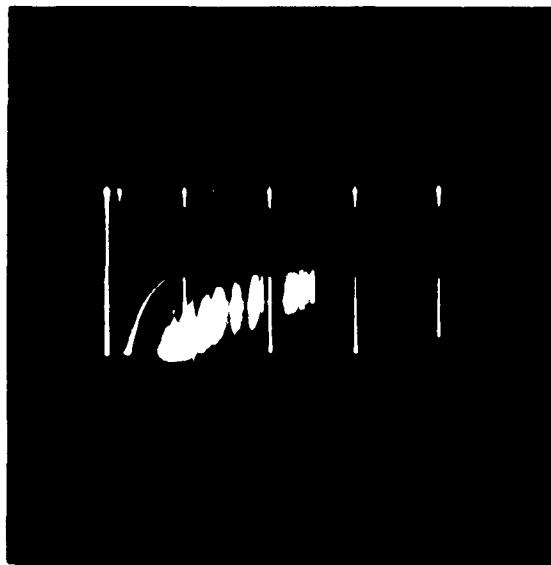
(a) Σ only.

(b) MRI.

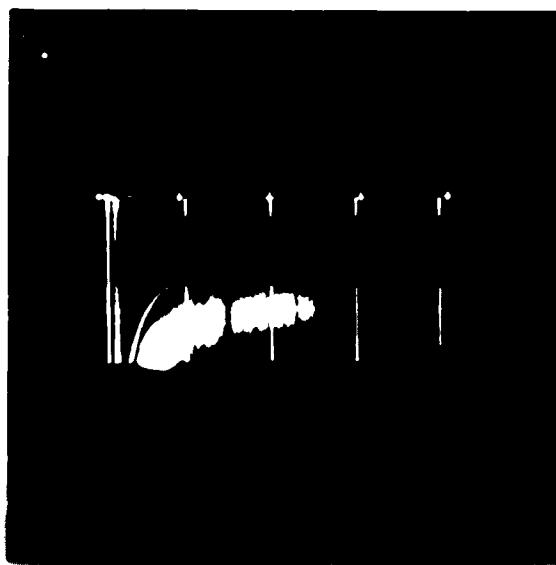
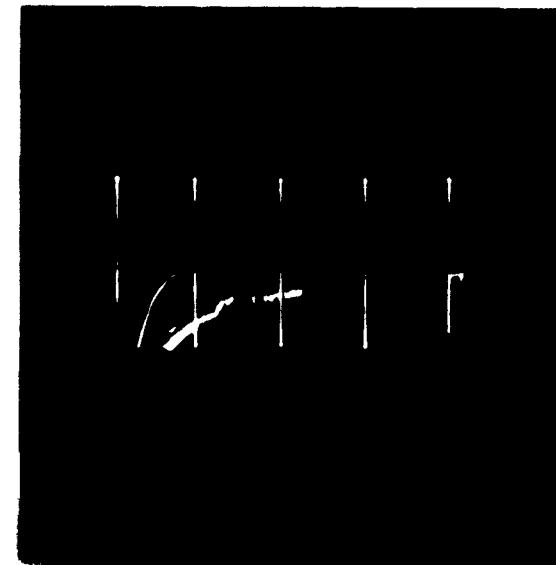
(c) Σ only.

(d) MRI.

FIG. 35. Terrain Clearance, E-Scan; Death Valley Area. Five-mile markers; note improvement in false target problem.

(a) Σ only.

(b) MRI.

(c) Σ only.

(d) MRI.

FIG. 36. Terrain Clearance, E-Scan, Mono Lake Area. Five-mile markers.

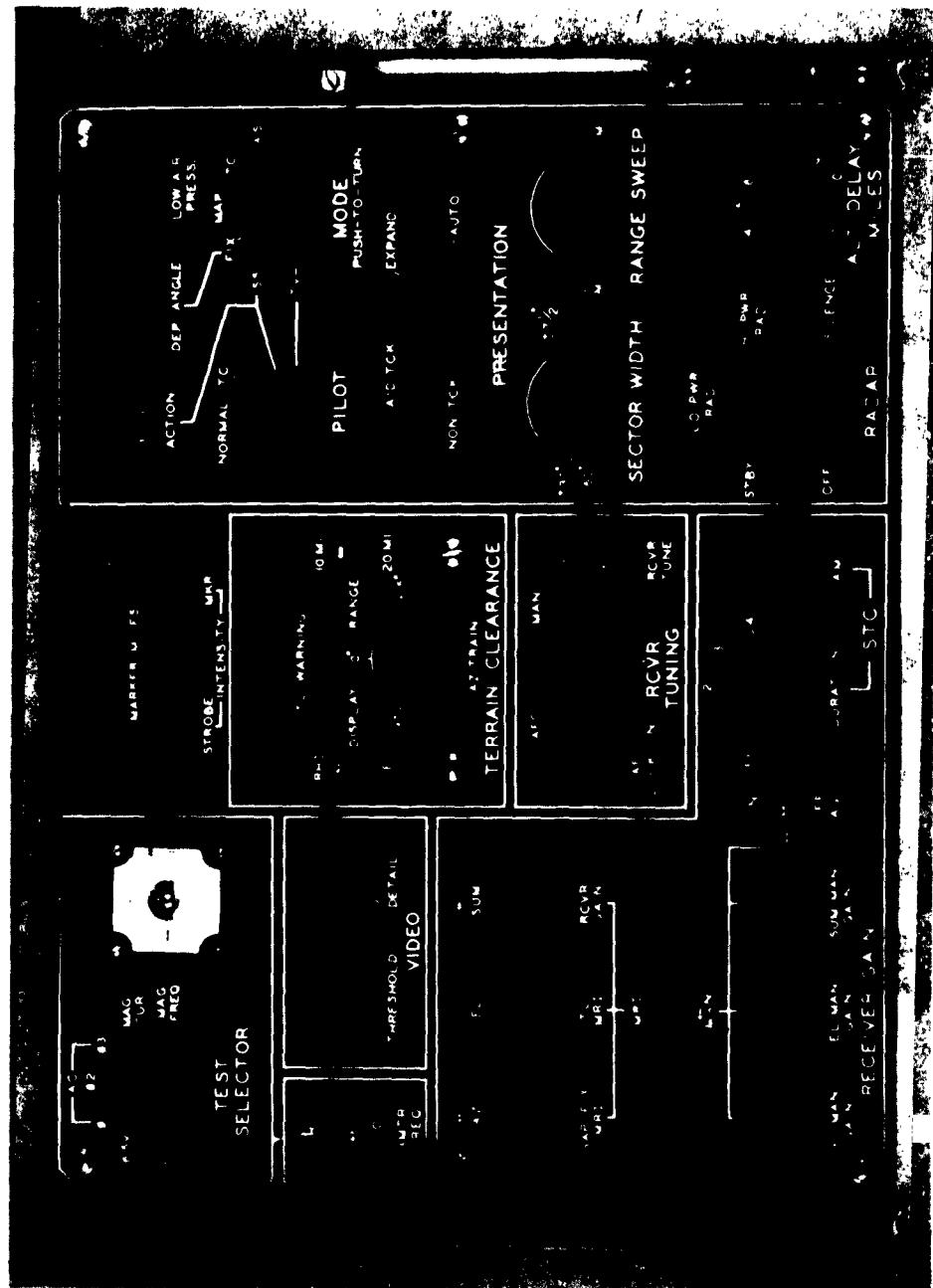


FIG. 37. Control Panel.

Appendix A

MODES OF OPERATION

The three major functions of the Radar Set Group OA-2003/ASB are search, bombing-navigation, and terrain clearance. Various modes of operation and combinations of these modes are available to perform these three functions either semiautomatically or by manual operation.

SEARCH MODES

In the Search (Mapping) mode (the MODE switch in the MAPPING (MAP) position, see Fig. 37), the radar set searches to a maximum range of 120 n. mi. The antenna radiates a pencil beam in azimuth with optional MRI, and with its spoiler section radiates a fan beam in the vertical plane.

Search—Unexpanded Mode

For the Search—Unexpanded mode, the pulse width is 3.0 μ sec at a PRF of 300 pps (duty cycle 0.0009). The antenna scans a fixed 120-degree sector at one look per second, with the scan center aligned to the ADL. Altitude delay is used in conjunction with the depressed-center PPI presentation so that the display tube area is used to the best advantage, and the sweep length can be adjusted from 120 to 10 n. mi. The azimuth line of the display can be aligned with respect to a specific target by manually operating the computer control stick.

The antenna's center of scan will track a selected point of interest while in the Search—Unexpanded mode when manual controls are used. After the operator has positioned the cross hairs at a chosen point by using the control stick, the antenna's scan angle and the degree of expansion on the display are manually adjusted by using the SECTOR WIDTH and the RANGE SWEEP dials, respectively. The scan angle of the antenna is varied from ± 30 to ± 7.5 degrees, centered about the LOS. At a point when the target is within 40 n. mi., the PRESENTATION switch is turned to the AIDED TRACKING (AID TCK) position to keep the selected point of interest at the intersection of the cross hairs.

Search—Expanded Mode

In the Search—Expanded mode (PRESENTATION switch in EXPAND position), the target previously selected in AIDED TRACKING is tracked by the antenna in azimuth and is kept centered in the display automatically. The pulse width is 0.25 μ sec at a PRF of 1,200 pps (duty cycle 0.0003). The antenna scans a sector that is variable, inversely as a function of range, from 60 to 15 degrees centered about the LOS. On the indicator, the sweep length can be from 120 to 10 n. mi. Both the degree of expansion and the scan angle are automatically adjusted by the position of the range strobe line and the RANGE SWEEP control to allow for maximum use of the display tube area.

Search—Automatic Mode

In the Search—Automatic mode (the PRESENTATION switch in the AUTOMATIC (AUTO) position), the antenna scan angle is fixed at 15 degrees and the scan rate at five looks per second. The expansion of the display increases gradually with decrease in range to the target until it reaches the maximum size of the display, 2.5 miles, at 10 n. mi. range. The target is tracked automatically by the antenna, and its position is kept at the intersection of the cross hairs on the presentation. Both Search—Expanded and Search—Automatic modes are used within a range of 45 n. mi.

Search—Single Scan

For any of the search modes, the operator has a choice of using a continuous-scan or a single-scan method of radiating. When the MODE switch is at the SINGLE SCAN (SS) position, momentarily depressing the ACTION button causes the antenna to radiate during one full scan and then to return automatically to the nonradiating state. The presentation is stored for future use on an indirect-view storage tube in the RSU. Radar silence can thus be maintained, since the stored presentation can be redisplayed at will on the two indicator displays. This function also permits the pilot and the operator to view separate displays simultaneously. The originally stored presentation is automatically erased when a new scan is recorded in the RSU.

BOMBING—NAVIGATION MODES

In the Bombing—Navigation (Fix) mode of operation (the MODE switch in the FIX position), the pencil beam is used with optional MRI in azimuth and in elevation. The antenna scan rate and the sector width (to 60 degrees maximum) are automatically controlled by the range to the target and the degree of expansion of the display. In this mode, the pulse width and the PRF are the same as those in the Search—Expanded operation; the radar operates in this mode to a maximum range of 45 n. mi.

The antenna is initially positioned in elevation by the depression-angle output of the bombing-navigation system computer. The LOS is automatically positioned in azimuth and, after being depressed to the proper angle at the start of the bombing-navigation function, the radar tracks in elevation while scanning in azimuth. As it continues to track the target, depression-angle values become a radar output and are used to correct those in the computer.

In all Bombing-Navigation (Fix) modes, the DEPRESSION ANGLE (DEP ANGLE) indicator lamp on the control panel will light when the range strobe coincides with the MRI target and is tracking satisfactorily. This signal indicates to the operator that the depression-angle output of the radar is valid and can be used for correcting the depression-angle value in the computer. The antenna is capable of tracking a target in elevation to the maximum antenna limit of -55 degrees, except when limited by aircraft pitch.

The presentation is the depressed-center PPI display with optional altitude delay.

Fix-Expanded Mode

In this mode, the presentation expands gradually, with the point of interest automatically centered in the display. The antenna's scan angle is automatically controlled, for maximum illumination of the target area, by the position of the range strobe line and the RANGE SWEEP control. The antenna's scan angle will vary from 60 to 15 degrees (depending on range and display expansion) as the scan rate varies from two to five looks per second.

Fix-Automatic Mode

The antenna continues to track in azimuth and in elevation in this mode as in the Fix-Expanded mode, and depression-angle values are corrected in the computer. The sector of the antenna scan is fixed at 15 degrees, and the display is the same as in the Search-Automatic mode.

Altitude Set Mode

This mode (the MODE switch in the ALTITUDE SET (AS) position) is used to correct the computer altitude normally obtained from barometric data computation. The spoiler section of the antenna is used to create a fan beam in the vertical plane, and the antenna is depressed to the full mechanical limit of 55 degrees while scanning a fixed 15-degree angle in azimuth. The range strobe line is automatically centered in the display, and the presentation is expanded about this line. The control stick is then used to position the range strobe line to the first ground return, thus correcting the computer's altitude value.

TERRAIN CLEARANCE MODE

In the Terrain Clearance mode (the MODE switch in the TERRAIN CLEARANCE (TC) position), the radar antenna scans a 25-degree angle in elevation, from +10 degrees to -15 degrees with respect to the line of flight (LOF). It can be manually slewed in azimuth to 15 degrees on either side of the azimuth reference. Azimuth stabilization to the ground track can be selected. The scan rate is one look per second, and only the pencil beam is used. MRI is employed in elevation for beam sharpening.

By setting the DISPLAY switch, the operator may select an E-scan or a RANGE HEIGHT INDICATOR (RHI) presentation. A fixed 1,000-foot clearance line is established on the indicator. The display can have either a 10- or a 20-mile range scale.

OTHER MODES**Television Mode**

This mode (the MODE switch in the TELEVISION (TV) position) was intended to provide a television display for the operator while the pilot was operating the radar in the Terrain Clearance mode. This mode was not used in testing the experimental model, since the television sight unit arrived at NOTS too late to be installed. The television system will be tested as a part of the evaluation of the developmental model.

Emergency Mode

Specifications required an Emergency mode of operation that would permit reduced search functions to be performed. The equipment that arrived at NOTS did not offer this function.

Appendix B

FUNCTIONAL DESCRIPTION OF EQUIPMENT

Radar Set Group OA-2003/ASB comprises the following units: antenna, transmitter-modulator, receiver, synchronizer, servo, control, and three indicators. The functional description of these units is detailed in the following sections.

ANTENNA ASSEMBLY

The antenna dish is a 16-by-26-1/2-inch parabolic reflector with a hinged top section (the spoiler) that provides for a change in elevation beam pattern (Fig. 1, 2, and 3). The antenna assembly is variably controlled in tilt by the track-while-scan monopulse tracking servomechanism or is fixed to a reference in the Search and Bombing-Navigation (Fix) modes. Tilt is controlled by the depression axis programmer in the Terrain Clearance mode and is fixed at -55 degrees in the Altitude Set mode.

The antenna is fed RF energy through the four-horn feed, waveguide, and comparator sections that are pressurized and mounted on the antenna. The beam pattern without the use of the spoiler and with monopulse resolution improvement is a pencil beam 1.8 degrees in azimuth and 3.2 degrees in elevation. In the Search and Altitude Set modes of operation, with the spoiler section down, the beam pattern remains a pencil beam in azimuth but becomes a fan beam in the vertical plane. The vertical pattern is optimized for an altitude of 40,000 feet above the terrain.

The scan rates of the antenna are controlled by the azimuth scan programmer. The rate for slow scan in the Search mode is one look per second over a 120-degree sector, and for rapid scan from two to five looks per second over a 60- to 15-degree sector. The scan rates are controlled by the sector width to provide for the best illumination of the target.

In all modes except Search (120-degree sector) and Terrain Clearance, the center line of the azimuth scan angle is stabilized to the relative bearing angle; for the ± 30 -degree scan in the Search mode, the antenna scan is referenced to the ADL; in Terrain Clearance, the antenna is stabilized in azimuth to the aircraft drift angle, and relative to this, the antenna can be manually trained ± 15 degrees in azimuth while automatically scanning in elevation; and, in elevation, the antenna is stabilized to the angle of attack.

TRANSMITTER-MODULATOR

The transmitter-modulator (Fig. 38) consists of a hydrogen thyratron modulator and associated high-voltage power supply, a magnetron, a dummy load, a ferrite load isolator, and a magnetron tuning drive. The high-voltage power supply is a conventional d.c. resonant charging circuit.

The magnetron, a Litton L3101, tunable over the range of 16.05 to 16.95 gc, is protected from detrimental effects of standing waves by a ferrite load isolator. The total output from the magnetron through the load isolator is 60 kw. Mechanical tuning is provided for by the magnetron tuning drive motor at a rate of 125 Mc/sec.

A dummy load is provided as part of the circuitry; when radar silence is selected, the RF energy is directed into the dummy load.

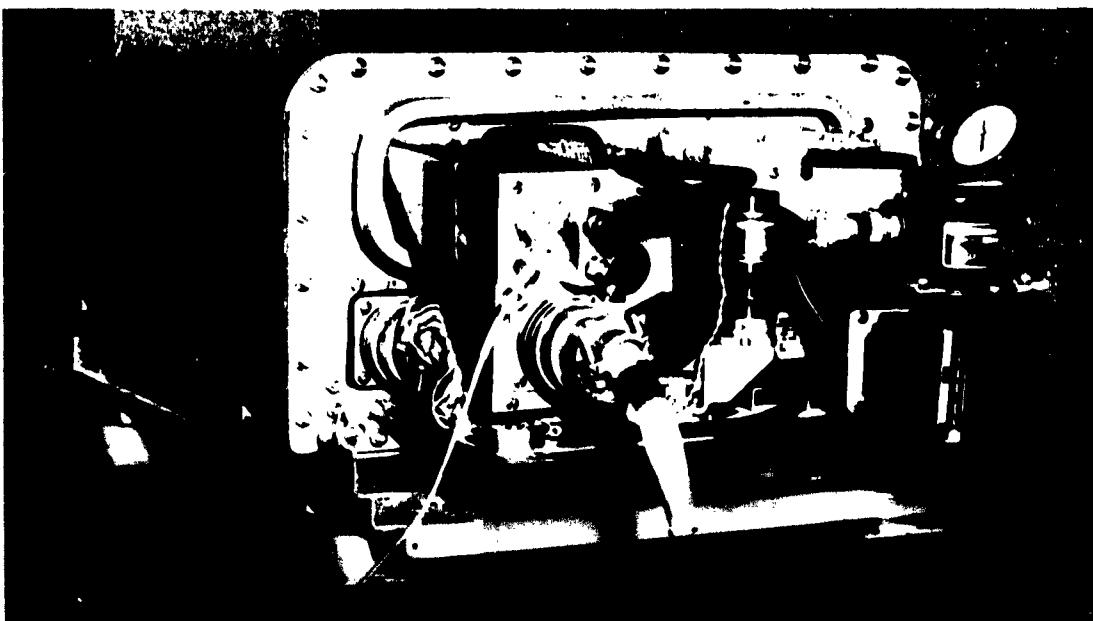


FIG. 38. Transmitter-Modulator.

RECEIVER

The receiver unit (Fig. 39) consists of the components in the antenna section and the receiver section, described in the two following subdivisions. The transistorized power supply for the receiver, which delivers all the alternating current (a.c.) and d.c. voltages for the receiver, is mounted on the receiver case.

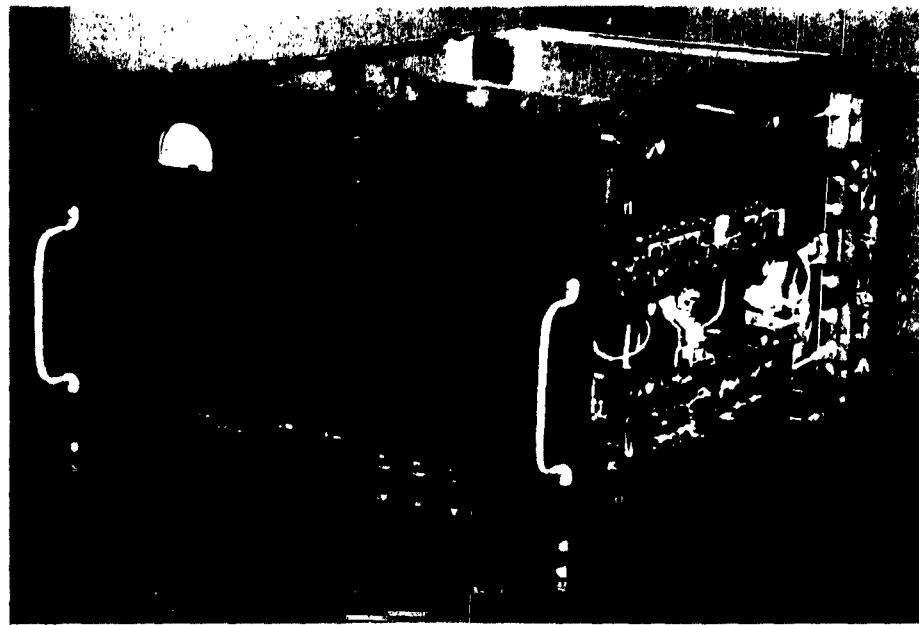


FIG. 39. Receiver.

ANTENNA SECTION. To restrict losses in signal strength caused by waveguide attenuation and multiple rotary joints, all microwave components were physically mounted to the rear of the reflector on the elevation axis of the antenna (see Fig. 1). This assembly consists of the transmit-receive (T-R) duplexer, the directional coupler, the klystron local oscillator, the balanced crystal mixers, and four identical pre-IF amplifiers having a 20-db gain.

The comparator (Fig. 40) is composed of two broad-band phase shifters, two 3-db, short-slot hybrids, two folded-T hybrids, and a waveguide termination. Each phase shifter is composed of two phase-shifting sections which together produce a total shift of 90 degrees by providing a 35-degree lead in one section and a 55-degree lag in the other section. In the 3-db, short-slot hybrids, the incoming signals either reinforce or cancel each other in combinations, to result in a Σ , an azimuth Δ , and an elevation Δ signal.

Through the waveguide transmission lines, these three signals are sent to the waveguide assembly. A part of this assembly consists of the four balanced crystal mixers, where three of the modified signals are independently heterodyned with the local oscillator frequency to produce three IF signals. The mixer crystals are protected during the time the transmitter is pulsed by T-R tube assemblies on the waveguide transmission lines. The fourth mixer receives a sample of the magnetron power, extracted for the AFC circuit by the directional coupler, which is used to maintain the constant 60-Mc difference in frequency between the output of the magnetron and that of the local oscillator.

The heterodyned Σ , azimuth Δ , elevation Δ , and AFC signals are amplified by four pre-IF amplifiers that are part of the assembly mounted on the back of the radar antenna. The four amplifiers are identical, and have a gain characteristic of 10 db, a bandwidth of 18 Mc, and a noise figure of 2 db or less.

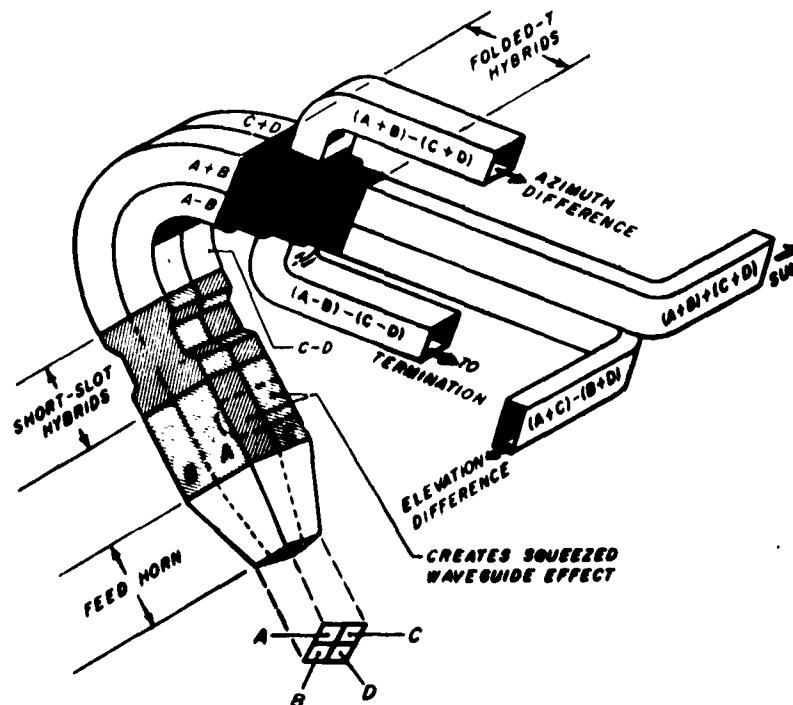


FIG. 40. Comparator and Four-Horn Feed Assembly.

RECEIVER SECTION. The separate receiver portion consists of three 60-Mc IF strips for the Σ , the azimuth Δ , and the elevation Δ signals, the STC, the AFC, the overload automatic gain control (OAGC), the instantaneous automatic gain control (IAGC), the video processing unit, and the MRI unit. For each of the three main signal channels there is a rear section preamplifier between the preamplifier and postamplifier with a 27-db gain characteristic.

The post-IF amplifiers, located in the receiver box, provide an additional gain of 65 db before the signals are processed in the MRI unit.

Sensitivity Time Control. The STC is activated by the pretrigger pulse from the synchronizer unit, and it controls the receiver gain (1) before the time of the transmitted pulse and (2) during the time that near radar returns are being received. Receiver gain is decreased initially during the time the transmitter is radiating. The trailing edge

of the pulse from the STC is shaped so that the receiver's sensitivity is gradually increased in time as the more distant echoes arrive. The STC pulse is applied to the suppressor control grid tube in the pre-IF amplifier. This pulse amplitude and its recovery time are independently adjustable by controls on the radar control panel.

Automatic Frequency Control. Automatic control of the klystron local oscillator's frequency is accomplished by the AFC circuitry composed of a directional coupler, a balanced crystal mixer, a pre-IF amplifier, a 60-Mc discriminator, and a servoamplifier and motor to tune the klystron local oscillator.

The sampled transmitter signal is mixed with the local oscillator frequency in the AFC balanced crystal mixer and then amplified in the pre-IF amplifier for the AFC circuitry.

The sampled signal provided by the directional coupler is 60 db down from the magnetron power output. The transmitter signal to the AFC crystal mixer is further reduced in power by a variable attenuator inserted in a wall of the waveguide section. This attenuation may be varied from 3 to 20 db.

The klystron is tuned electrically and mechanically by the 60-Mc discriminator circuit and servo. The discriminator has a very limited range of 10 Mc, and its lock-on relay is energized when the difference frequency is 65 Mc.

The frequency of the klystron can be controlled manually ± 10 Mc by placing the RECEIVER TUNING switch in the MANUAL position. The operator can then use the RECEIVER TUNE knob, which varies the voltage applied to the klystron reflector. When the switch is returned to the AFC position, a relay is energized and the AFC returns to the track mode.

During silence in Single Scan operation, the AFC does not receive a sample of the magnetron frequency; when transmission is resumed, the circuit is able to resume tracking. When the waveguide switch is in the dummy load position, a standby relay is energized that removes 28 volts from the servoamplifier and prevents the servomotor from changing the frequency of the klystron local oscillator.

Overload Automatic Gain Control. The negative sum video signal is the input to the OAGC circuit, which is provided to prevent receiver overloading. When the voltage level of this video signal reaches a previously defined level, near the overload point, the circuit releases a negative d.c. output. This signal is superimposed on the gain controls to lower the gains of the three post-IF amplifiers. This circuit was disconnected during the testing program.

Instantaneous Automatic Gain Control. The sum amplifier contains an IAGC circuit composed of a detector, an amplifier, and a cathode follower. This circuit supplies feedback to certain of the IF amplifier stages and reduces the gain during the time of strong signal returns. All received signals over a certain amplitude are reduced to improve the dynamic range and provide an even distribution of returned signal strengths, thus furnishing better definition on the scope presentations. The reduction of all signals that are over a certain level of amplification also provides a degree of immunity from radar jamming; otherwise, the long decay time of a strong signal return blocks out other true target returns. The gain of the elevation and azimuth amplifiers is controlled by the sum IAGC.

Video Processing Unit. The video processing unit (1) mixes the unblanking gate and the marker pulses and (2) combines these with the radar video to provide a composite output for the indicators and the RSU.

The circuit is a variable high-pass filter for signals above a certain amplitude threshold level; the height of the unblanking pedestal after amplification determines the amount of video amplification that is allowed passage. For signals below the threshold level the circuit acts as a broad-band stage; this level is set by the threshold control available to the operator.

Monopulse Resolution Improvement Unit. The MRI circuit functions to combine the Σ , elevation Δ , and the azimuth Δ video signals, thus sharpening radar target returns by synthetically narrowing the beamwidth.

The inputs to the azimuth channel are the amplitude detected Σ signal and the azimuth Δ signal. The azimuth Δ signal and the Σ signal enter a differential amplifier 180 degrees out of phase, so the output is the result of subtracting the two signals. The video signal thus produced represents an improved resolution of the target return which is then applied to a cathode follower and clipper and is transmitted to the video processing unit as the azimuth input.

In the elevation channel, the phase-detected Δ video (S-curve) input is amplified and two outputs are provided. One goes through a cathode follower to the track-while-scan circuitry. The other is applied to a paraphase amplifier whose outputs are full-wave rectified and combined so that the single resulting output is the complete elevation Δ signal. This is combined with the Σ signal in the MRI differential amplifier. The resolution-improved elevation return is applied to a cathode follower and clipper and is then the elevation input to the video processing unit.

SYNCHRONIZER

The synchronizer (Fig. 41) provides the radar system with basic time references and controls, and generates the range strobe line, the range markers, the altitude markers, and the clearance line for the Terrain Clearance mode. The unit consists of the range strobe generator, the marker generator, the sweep generator, and the track-while-scan circuitry.

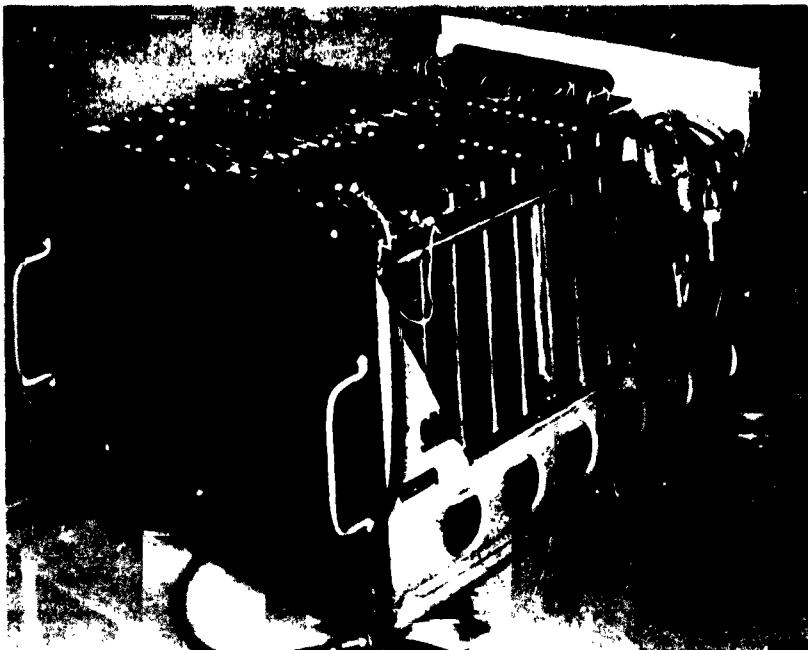


FIG. 41. Synchronizer.

RANGE STROBE GENERATOR. A Pierce crystal oscillator operating at 40.457 kc is used for accurate timing control between the modulator trigger pulse and the range strobe generator. The output of the crystal oscillator goes to a fixed-peaker generator and to the range resolver. The peaker generator produces an output pulse for each input cycle, or each 2 n. mi. The 2-n. mi. range is further resolved by a Meecham generator to an accuracy of 10 feet.

The PRF generator provides synchronized timing trigger pulses to the range strobe generator, the basic sawtooth generator, and the modulator unit. A noise generator causes the PRF to jitter randomly $\pm 10\%$ about the preset frequency of the PRF generator in order to provide a degree of antijamming protection.

MARKER GENERATOR. The marker generator produces the 2-, 5-, 10-, or 20-mile range markers. This unit also produces the sector gate used in the generation of the clearance line for the Terrain Clearance mode. The sector gate synchronizes the occurrences of the range markers with the beginning of the sweeps.

The sweep generator unit consists of a pulse distribution unit, the range gate unit, the basic saw generator and saw limit comparator, the north-south (N-S) sweep amplifier, resolver drive, etc. The functions performed in this circuitry are those concerned with generating and stabilizing the basic sawtooth waveform, and generating the azimuth and range strobe lines.

The pulse distribution unit receives the basic timing pulses from other circuits in the synchronizer and changes their amplitude and/or polarity to make them usable by the sweep generator and the sweep control unit.

The saw generator produces a sawtooth waveform that is the basis for generating all of the display sweeps. The generation of the saw is accomplished by a gated Miller integrator started by the pretrigger pulse. When the voltage level of the saw is compared with that of the output of the range servo unit, it serves as a voltage-versus-time reference that is indicative of range.

The sawtooth voltage level is compared with the range voltage from the range servo unit in the range gate unit. When these voltage levels coincide, one of the pulses from the phase-shifted string of peaker pulses from the range strobe generator is gated out and becomes the range strobe line.

Using the basic sawtooth waveform as an input, the resolver drive produces rectangularly resolved sweeps that are either the vertical, N-S, or the horizontal, east-west (E-W), component. The azimuth line for the depressed-center PPI display is produced by collapsing one E-W sweep and generating the azimuth line during this time. The azimuth line gate, using a modified pretrigger pulse, gates out a pulse that disables the saw generator while the azimuth line is generated.

TRACK-WHILE-SCAN CIRCUITRY. During track-while-scan operation, range information is fed to the radar from the system computer; and by continually positioning the antenna in depression, the radar furnishes the depression-angle values. The track-while-scan circuitry consists of the S-curve generator, range strobe generator, discriminator integrator, and relay driver.

When the S-curve crossover point and the range strobe pulse are not coincident, the sensing unit transmits an error voltage through an integrator to the elevation servo to drive the antenna until the two signals

are in coincidence. Once this has been accomplished, the sensing unit is disabled and a signal to the antenna-positioning mechanism is derived from the discriminator integrator.

The relay driver disables the sensing unit when its error signal is at minimum, and the discriminator transmits an error signal to the integrator. The discriminator network uses the elevation difference video and the range strobe, and continually repositions the antenna to bring the range strobe pulse and the S-curve into coincidence. A d.c. tachometer damps antenna oscillations by furnishing a signal (of proper polarity) proportional to antenna velocity.

SERVO UNITS

Servo Unit No. 1 (Fig. 42) contains the azimuth-scan and depression-scan programmers, and the switches and controls. Unit No. 2 (Fig. 43) contains the servoamplifiers for roll and pitch and azimuth stabilization.

In roll, the stabilization limits are ± 30 degrees, and in pitch, $+40$ degrees and -30 degrees. The azimuth scan limits are ± 60 degrees. For the Terrain Clearance mode, the antenna scans in depression from 10 degrees above to 15 degrees below the LOF (angle of attack). The roll and pitch stabilization signals are received from the stable platform.

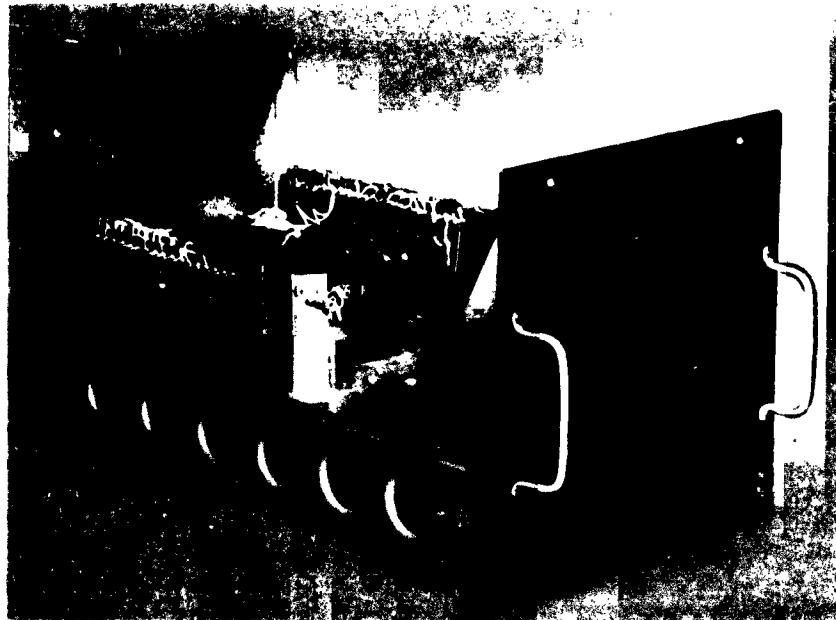


FIG. 42. Servo Unit No. 1.

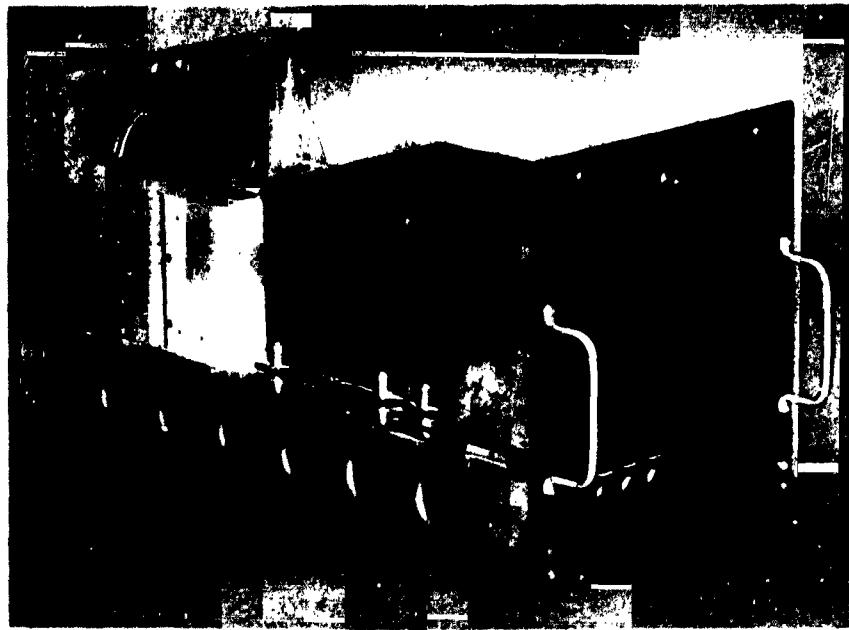


FIG. 43. Servo Unit No. 2.

Azimuth-scan control is accomplished through the azimuth-scan programmer and the servo and scan controller. The azimuth-scan programmer, an integral part of the azimuth axis servo loop, programs the antenna scan in azimuth and controls the scan width (about the center line determined by the azimuth heading servo).

In the Altitude Set mode, the antenna is depressed to the mechanical limit of -55 degrees, and in the Terrain Clearance mode, the antenna scans from +10 to -15 degrees in the vertical plane. The scan is controlled by the depression-scan programmer, which is a synchro driven by a synchronous motor.

CONTROL UNIT

The control panel shown in Fig. 37 was built only for use in testing the experimental model. These controls and switching functions would normally be incorporated into the over-all control unit for the bomb-directing set of which the radar is a subassembly.

MODE and PRESENTATION controls are on the right third of the control panel. All of these controls are for the use of the operator, with the exception of the PILOT switch. When it is in the NORMAL position, single-scan operation is being performed by the radar; when it is in the TC position, the pilot has terrain-clearance information on his indicator while the navigator re-views a stored presentation.

The center portion of the control panel contains the range edge MARKER controls, TERRAIN CLEARANCE, and RECEIVER TUNING controls. During the time the PILOT switch is in the TC position, the TERRAIN CLEARANCE controls will be at the disposal of the pilot, since his presentation is not necessarily the same as the navigator's. Two toggle switches give a choice of RHI or E-scan displays, and of 10- or 30-mile range scales.

The left third of the control panel has the TEST SELECTOR, VIDEO, TRANSMITTER FREQUENCY, MRI, RECEIVER GAIN, OAGC, and STC controls.

RECORDING STORAGE UNIT AND INDICATORS

The units that provide for the storage and display of radar presentations are the RSU, the navigator's indicator, and the pilot's indicator. The presentations available are depressed-center PPI, expanded PPI variable between 10 and 120 n. mi., fixed (expanded) PPI for 10- or 20-mile range sweeps, and either RHI or E-scan for the Terrain Clearance mode.

RECORDING STORAGE UNIT. The RSU (Fig. 44) stores the radar presentations when the Single Scan mode is used. This permits the navigator to re-review a stored presentation while radar silence is being maintained or while the pilot is using the Terrain Clearance mode. In this mode, use of the SS ACTION button turns the transmitter-receiver on during one scan of the antenna. The terrain-clearance presentation is disrupted momentarily when the antenna reverts to the Search mode for one scan,

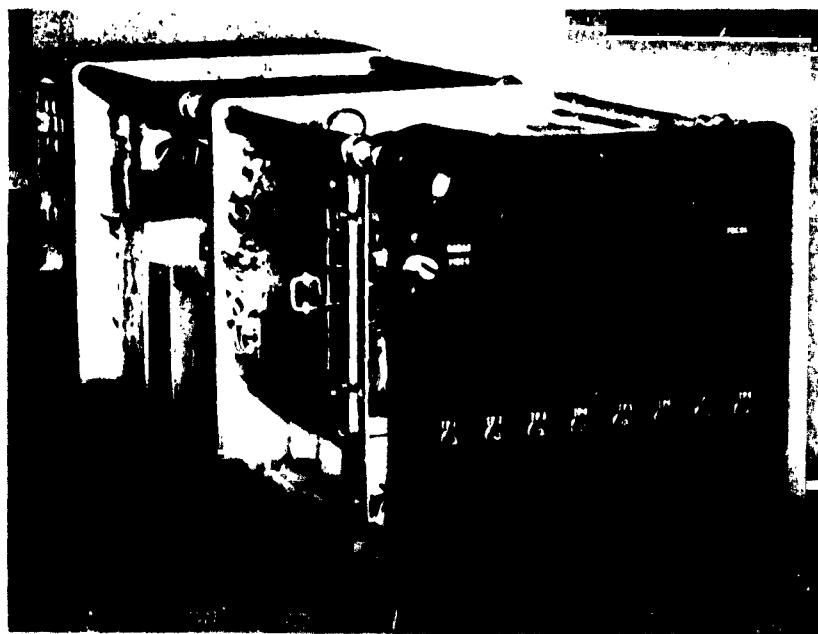


FIG. 44. Recording Storage Unit.

but is resumed in about four seconds. In the same length of time, the new picture stored in the RSU will be shown on the navigator's indicator. The recorded picture can be rewritten on the navigator's indicator during the next 5- to 10-minute interval. The length of time the picture is retained by the RSU depends on the number of times it is rewritten on the navigator's indicator.

The four modes of operation of the RSU are Erase, Prime, Write, and Read. The first three of these accomplish the recording function, and Read is considered the normal mode for the unit. These modes are controlled by relays in the programmer unit of the RSU.

NAVIGATOR'S INDICATOR. The navigator's indicator (Fig. 45) uses a conventional electrostatically deflected and focused CRT, type 5FP14A. All circuits are conventional with the exception of the sweep generators, which are designed to interchange the N-S and E-W sweeps for the Search and Terrain Clearance modes. The navigator's indicator was used for photographic purposes during the testing period and all radar photos contained in this report are of this display tube.



FIG. 45. Navigator's Indicator.

PILOT'S INDICATOR. The pilot's indicator (Fig. 46) uses a 5-inch, direct-view storage tube, type RCA 6866, with associated circuitry for single-scan storage and erase functions. The tube has a long-persistence screen coating that will retain an image until erased, or for approximately five minutes. Time sharing of indicator functions is provided for.



FIG. 46. Pilot's Indicator.

JUNCTION BOX

The primary function of the junction box (Fig. 47) is the distribution of power.

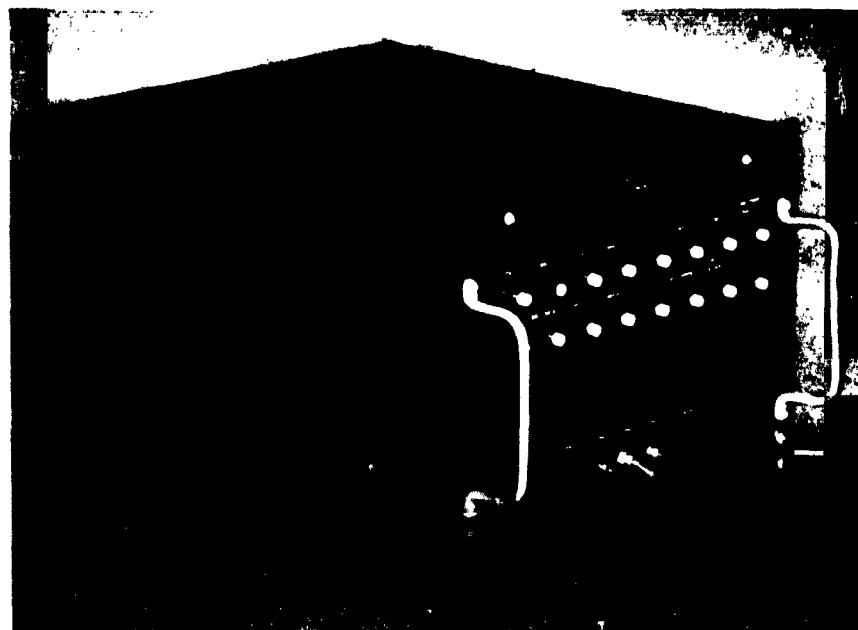


FIG. 47. Junction Box.

INITIAL DISTRIBUTION

30 Chief, Bureau of Naval Weapons

CD (1)	RAAV-6 (1)
CW (1)	RAAV-81 (4)
DLI-31 (2)	RM (1)
R (1)	RM-3 (1)
R-2 (1)	RM-371 (1)
R-3 (1)	RM-373 (1)
RA (1)	RMGA-4 (1)
RA-2 (1)	RMWC (1)
RA-3 (1)	RMWC-4 (1)
RAAV (1)	RT (1)
RAAV-2 (2)	S (1)
RAAV-21 (1)	SEL (1)
RAAV-22 (1)	

2 Chief of Naval Operations

OP-55 (1)
OP-721D (1)

1 Chief of Naval Research (Code 104)

1 Air Development Squadron 5, Naval Air Facility, NOTS

7 Fleet Air Whidbey

1 Heavy Attack Squadron 2 (VAH 2)

1 Heavy Attack Squadron 4 (VAH 4)

1 Heavy Attack Squadron 6 (VAH 6)

1 Heavy Attack Squadron 8 (VAH 8)

9 Heavy Attack Wing 1, Sanford

1 Naval Air Development Center, Johnsville

1 Naval Air Test Center, Patuxent River

1 Naval Avionics Facility, Indianapolis (Library)

1 Naval Ordnance Laboratory, Corona

1 Naval Ordnance Laboratory, White Oak (Library)

1 Naval Postgraduate School, Monterey

2 Naval Research Laboratory

1 Naval Weapons Laboratory, Dahlgren (Technical Library)

2 Naval Weapons Services Office

1 Navy Electronics Laboratory, San Diego

1 Operational Test and Evaluation Force

1 Navy Liaison Officer, Tactical Air Command, Langley Air Force Base

1 Aberdeen Proving Ground (Ballistic Research Laboratories)

1 Army Electronic Proving Ground, Fort Huachuca (Technical Library)

1 Tactical Air Command, Langley Air Force Base (TPL-RQD-M)

1 Aeronautical Systems Division, Wright-Patterson Air Force Base (ASAPRD-Dist)

1 Air Force Cambridge Research Laboratories, Laurence G. Hanscom Field

1 Air Proving Ground Center, Eglin Air Force Base

1 Air University Library, Maxwell Air Force Base (AUL-6238)

10 Armed Services Technical Information Agency (TIPCR)

1 Defense Atomic Support Agency, Sandia Base

ABSTRACT CARD

U. S. Naval Ordnance Test Station
Evaluation of the Experimental Model of the Radar
Set Group OA-2003(XN-1)/ASB (U), by F. L. Guthlieben
and Sara G. Valdivia. China Lake, NOTS,
October 1962. 68 pp. (NAVWEPS Report 7763,
NOTS TP 2739), CONFIDENTIAL.
ABSTRACT. This report discusses the results of
the flight testing and evaluation of the experimental
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and Sara G. Valdivia. China Lake, NOTS,
October 1962. 68 pp. (NAVWEPS Report 7763,
NOTS TP 2739), CONFIDENTIAL.
ABSTRACT. This report discusses the results of
the flight testing and evaluation of the experimental
model of the Radar Set Group OA-2003(XN-1)/ASB. The
characteristics and performance of this equipment are

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NAVWEPS Report 7763

detailed, and certain improvements in design that were suggested for the developmental model are discussed.

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